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ENGINEERING AND DESIGN

PLUMBING AND GASFITTING - EMERGENCY CONSTRUCTION

HEADQUARTERS, DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS

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Office of the Chief of Engineers
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Table of Contents

This manual rescinds Sections II and III of Chapter XIV, Engineering Manual for Emergency Construction, January 1951 (EM 1110-345-555).

SECTION III
COMPRESSED AIR

SECTION I - PURPOSE AND SCOPE

1-01. PURPOSE AND SCOPE. This manual prescribes the standards of emergency construction to be used by all elements of the Corps of Engineers for the design of interior plumbing, gas, and compressed-air systems in buildings. These requirements may be altered when necessary to meet special conditions on the basis of good engineering practice consistent with the temporary nature of the construction.

SECTION II - PLUMBING

2-01. GENERAL. Plumbing today consists largely of assembling and installing manufactured products. The terms "Plumbing Installation" and "Plumbing System" as used herein, include the water-service pipe and the building drain from their connections in the building to points 5 feet outside of building, including all pipes, fixtures, vents, branches, devices, rain leaders, and storm branches connected thereto. The plumbing installations should be such as to safeguard health, and should be of the most economical arrangement. Consideration should always be given in the field to locations of buildings with reference to sewers and water mains, as these details govern the direction and runs for the branch piping. In all cases, the standard drawings should be adapted to apply to local conditions.

2-02. DEFINITIONS. Plumbing terms used herein will be as defined in American Standard ASA A40. 8, National Plumbing Code.

2-03. DRAWINGS AND SPECIFICATIONS. The preparation of drawings and specifications will be in accordance with the following conditions:

a. Drawings. The piping will be exposed and will be installed in locations that will permit maintenance and replacement without disturbing the building structure. In finished rooms, such as in hospitals, piping may be concealed or partially concealed; i. e., risers may be concealed and horizontal branches at ceilings may be exposed. Plumbing drawings are not to be considered as diagrammatic only, but will be accurate, to scale, and in sufficient detail to eliminate the need for shop drawings. All piping and equipment will be shown in their proper places. A legend showing piping symbols and abbreviations used on each drawing will be shown on each set of drawings. In the preparation of drawings, care will be taken to avoid interference with the work of other trades. It should be ascertained that all necessary electrical and heating outlets and connections required for plumbing equipment have been provided. The following standards and information will be used as guides in the preparation of drawings:

(1) Plumbing symbols for piping will conform to Military Standard Mechanical Symbols MIL-STD-17.

(2) Capacities of equipment. Capacities of all equipment required for each project, such as water heaters, storage tanks, air compressors, pressure regulators, sump pumps and ejectors, should be shown on each set of drawings.

(3) Water-service note. The following note shall be placed on each set of drawings: "Water-pipe sizes are based on a minimum working pressure of _____ pounds per square inch at a flow of _____ gallons per minute at the location where the main service enters the building.

b. Specifications. All references herein to specifications are to the latest edition of Guide Specifications for Emergency Construction.

2-04. FIXTURE REQUIREMENTS. The number of fixtures required in a building will be as prescribed under table I. The requirements are based on the maximum number of persons that may be assigned to the building at one time. Specific requirements in regard to personnel govern in determining the proportion for men and women or for officers and enlisted men in administration buildings or other similar types of office buildings. The proportion of 35 percent women, 35 percent officers, and 30 percent enlisted men of the building population may be assumed as a general rule for office-type buildings. The maximum number of persons for theaters and chapels will be based on the seating capacity; for industrial buildings, shops, hangars, warehouses, and similar-type buildings, on the number of employees; and for hospitals on the number of patients and the personnel assigned to the hospital in addition to the patients.

Table I - Plumbing-Fixture Requirements Based on Persons per Fixture

Type of Building	Water Closets	Lava-tories	Urinals	Showers	Bath-tubs	Drinking Fountains
Administrative Type of Building						
Male Up to 30	15	15	30	--	--	75
31 to 125	25	20	40	--	--	or
126 to 300	30	25	50	--	--	Less
Female Up to 30	15	15	--	--	--	
31 to 300	20	20	--	--	--	
Barracks[1]						
Enlisted Men	12	9	20	18	--	100
Enlisted Women	8	8	--	10	30	100
Civilian Men	12	9	20	18	--	100
Civilian Women	8	8	--	10	30	100
Dining Halls						
Civilian Patrons						
Male	200	200	300	--	--	500
Female	150	150	--	--	--	
Kitchen Personnel						
Male	20	15	40	--	--	--
Female	15	15	--	--	--	--
Gymnasium	30	30	40	15	--	100
Hospitals						
Patients	8-10	5-7	15-20	15-20	25	50
Employees Male	20	15	40	--	--	--
Female	15	15	--	--	--	--
Industrial Buildings						
Male	20	15	40	--	--	100
Female	15	15	--	--	--	100
Schools						
Male	40	25	40	--	--	100
Female	25	25	--	--	--	100
Bath Houses for Swimming Pools[2]						
Male	40	40	40	30	--	400
Female	20	40	--	30	--	
Theaters						
Male	250	200	250	--	--	400
Female	150	150	--	--	--	

[1] Each male toilet room in barracks should be equipped with a single-compartment laundry tray and one service sink. Single-compartment laundry tray should be provided for each group of 20 persons in women's barracks.

[2] Wet toilets are required for use by wet swimmers and are adjacent to the shower room. For men, wet toilets should consist of one water closet and one urinal; for women, one water closet for each group of 100 swimmers. The toilets should be so placed that persons using them must pass through the shower before entering the pool. The dry toilets serve the dressing rooms and are located off the dressing area.

2-05. FIXTURE UNITS AND BRANCH CONNECTIONS TO FIXTURES. Fixture-unit values designating the relative load weight for different kinds of fixtures and the sizes of branches for hot- and cold-water and waste connections to fixtures are shown in table II. Fixture units will be used in determining water-supply and drainage requirements:

Table II - Fixture Units and Size of Fixture Branches

	FU	CW	HW	W
Water closet, flush-tank	4	1/2	-	4
Water closet, flush-valve	8	1	-	4
Urinals (wall or stall)	4	3/4	-	2
Prophylactic-urinal	4	1	1/2	2
Service sinks	3	1/2	1/2	3
Flushing rim service sink	8	1	1/2	4
Surgical sinks	3	1/2	1/2	1-1/2
Sinks	2	1/2	1/2	1-1/2
Lavatories (Large PO plug)	2	1/2	1/2	1-1/2
(Small PO plug)	1	1/2	1/2	1-1/4
Bath tub	2	1/2	1/2	1-1/2
Sitz bath	2	1/2	1/2	1-1/2
Drinking fountains	2	1/2	-	1-1/4
Shower baths (Domestic)	2	1/2	1/2	2
(Group, per head)	3	1/2	1/2	
Continuous flow tubs	6	1/2	1/2	3

Table II - Fixture Units and Size of Fixture Branches (continued)

	FU	CW	HW	W
Arm and leg baths	3	1/2	1/2	2
Wash sinks	2	1/2	1/2	1-1/2
Laundry trays	2	1/2	1/2	1-1/2
Scullery sinks	4	3/4	3/4	2
Bain-marie	2	1/2	-	1-1/2
Dishwashers (Domestic)	2	1/2	1/2	1-1/2
(Commercial)	4	-	3/4-1	2
Steam kettles	-	1/2	-	-

FU - Fixture units
CW - Cold water
HW - Hot water
W - Waste

All dimensions are in inches.

Fixtures not listed in table II will be computed by use of table III.

Table III - Fixture Unit Values

Fixture drain or trap size (inches)	Fixture units
1-1/4	2
1-1/2	4
2	6
3	10
4	12

2-06. **SOIL, WASTE, VENT, AND DRAIN PIPING.** The proper operation of a plumbing system depends on the piping arrangement, with special attention given to the following conditions:

a. Soil and Waste Piping for Sanitary Systems. The minimum slopes will be as follows:

Minimum slopes

Fall per foot	Pipe diameters
Not less than 1/4 inch	1-1/4 to 3-inch diameters, inclusive
Not less than 1/8 inch	4- to 8-inch diameters, inclusive

No structural member will be weakened or impaired beyond a safe limit by cutting, notching, or otherwise, unless provision is made for carrying the structural load. Changes in direction in drainage piping will be made by the appropriate use of 45-degree wyes, half wyes, long-sweep quarter bends, sixth, eighth, or sixteenth bends or by combinations of these fittings, or by use of equivalent fittings or their combinations, except that sanitary tees may be used in vertical sections of drains or stacks, and short quarter bends may be used in drainage lines where the change in direction of flow is from the horizontal to the vertical. No change in direction greater than 90 degrees in a single turn will be made in drainage pipes.

(1) Cross connections. No fixture, device, or construction will be installed that will provide a backflow connection between a distributing system of water for drinking and domestic purposes and a drainage system, soil, or waste pipe, that would permit or make possible the backflow of sewage or waste into the water-supply system. No interconnection or cross connection will be made between a water-supply system carrying water meeting accepted standards of purity and any other water system.

(2) Protection of pipes. Pipes passing under or through walls will be protected from breakage. Pipes passing through or under cinder, concrete, or any other corrosive material will be protected against corrosion. No soil or waste pipe will be installed or permitted outside of a building or in an exterior wall unless adequate provision is made to protect it from freezing.

(3) Protection of electrical machinery. Water or drainage piping will not be located over electrical machinery or equipment unless adequate protection is provided against drip caused by condensation on the piping.

(4) Indirect waste. Wastes from stills and from equipment used for the sterilization of materials or for storage, preparation, or processing of food and drink will indirectly discharge to the drainage system through a trapped drain increaser or fixture with an airgap. The developed length of an indirect waste will be kept at a minimum with airgap. Drains from water tanks and discharge from hydraulic elevators will not be directly connected to the drainage system. The airgap will be at least twice the effective diameter of the indirect waste.

b. Pipe Sizes. Table II indicates fixture units for determining pipe sizes and the size of fixture branches. The fixture-unit values designate the relative load weights of different kinds of fixtures for estimating the total loads carried by a soil, waste, and drain pipe.

Table IV - Capacities of Soil and Waste Stacks. Horizontal Branches and Drains from More than One Branch Interval

Diameter of Pipe Inches	MAXIMUM FIXTURE UNITS THAT MAY BE CONNECTED							
	Building Drains or Sewers				One Horizontal Branch	Stacks with Not Over Three Branch Intervals	Stacks with Three or More Branch Intervals	
	Fall per Foot, Inches							
	1/16	1/8	1/4	1/2			One Branch Interval	Total in Stack
1¼					1	2	1	2
1½					3	4	2	8
2			21	26	6	10	6	24
2½			24	31	12	20	9	42
3		20[1]	27[1]	36[1]	20[2]	30[3]	11[1]	60[3]
4		180	216	250	160	240	90	500
5		390	480	575	360	540	200	1100
6		700	840	1000	620	960	350	1900
8	1400	1600	1920	2300	1400	2200	660	3600
10	2500	2900	3500	4200	2500	3800	1000	5600
12	3900	4600	5600	6700	3900	6000	1500	8400

[1] Not over two (2) water closets.
[2] Not over one (1) water closet.
[3] Not over six (6) water closets.

c. Vents and Venting. The seal of every fixture trap in a plumbing system should be adequately protected by a properly installed vent or system of venting. A stack vent, back vent, relief vent, dual

vent, circuit vent, or loop vent, or a combination of two or more of these forms, will be installed in the manner and within the limitations considered as adequate protection of trap seals.

(1) Stack vents. Every soil or waste stack will be extended vertically as a stack vent to at least 6 inches above the highest horizontal branch and then to the open air above the roof; or the stack vent and vent stack may be connected together within the building at least 6 inches above the flood level of the highest fixture, with a single extension from the connection to the open air.

(2) Vent stacks. A vent stack or main vent will be installed with a soil or waste stack whenever relief vents, back vents, or other branch vents are required in two or more branch intervals. The vent stack will terminate independently in the open air above the roof or may be connected with the stack vent, and will connect with the soil or waste stack through, at, or below the lowest horizontal branch or with the primary branch of the building drain.

(3) Distance of trap from vent. Except for water closets, pedestal urinals, trap standard service sinks, and other fixtures that depend on the siphon action for the proper functioning of the fixture, each fixture trap will have a protecting vent so located that the total fall in the fixture drain from the trap weir to the vent fitting is not more than 1 pipe diameter, and the developed length of the drain from trap weir to vent fitting is not less than 2 pipe diameters or more than 48 pipe diameters. A back or relief vent, preferably in the form of a continuous waste and vent, will be installed within these limits as may be necessary for compliance with this requirement.

(4) Dual vents. A dual vent for two fixture traps installed as a vertical continuous waste and vent, or a stack vent in a dual capacity, may be employed under the following conditions. No additional vents will be required for the traps thus vented. When both fixture drains connect with a vertical drain or stack at the same level, the developed length and total fall of each of the two fixture drains are within the limits given in subparagraph c(3).

(5) Group vents. A lavatory trap and a bathtub or shower-stall trap may be installed on the same horizontal branch with

a back vent for the lavatory trap and with no back vent for the bathtub or shower-stall trap, provided the vertical section of the lavatory drain is of not less than 1-1/2-inch diameter, and provided the developed lengths of both fixture drains are within the limits given in subparagraph c(3).

(6) Size of back vents and relief vents. The nominal diameter of a back vent, when required, will be not less than 1-1/4 inches nor less than 1/2 the diameter of the drain to which it is connected, and under conditions that require a relief vent for approved forms of group venting, the sum of the cross sections of all vents installed on the horizontal branches in one branch interval will be at least equal to that of either the main vent or the largest horizontal branch in the branch interval.

(7) Frost closure. In cold climates, adequate provision will be made to guard against frost closure of vents by increasing the pipe diameter at least one pipe size for vents up to 3 inches in diameter before passing through the roof.

(8) Location of vent terminals. No vent terminals from the sanitary drainage system will be within 12 feet of any door, window, or ventilating opening of the same or an adjacent building unless it is at least 3 feet higher than the top of such opening. Extensions of vent pipes through a roof will terminate at least 1 foot above the roof and properly fastened thereto.

d. Circuit Vents and Loop Vents.

(1) Battery venting. A branch soil or waste pipe to which two, but not more than eight water closets (except blowout type), pedestal urinals, trap standard to floor, shower stalls, or floor drains are connected in battery, shall be vented by a circuit or loop vent which will take off in front of the last fixture connection. In addition, lower-floor branches serving more than three water closets will be provided with a relief vent taken off in front of the first fixture connection. When lavatories or similar fixtures discharge above such branches, each vertical branch will be provided with a continuous vent.

(2) Dual branches. When parallel horizontal branches serve a total of eight water closets (four on each branch), each branch will be provided with a relief vent at a point between the two most distant water closets. When fixtures other than water closets discharge above the horizontal branch, each such fixture will be vented.

(3) Vent connections. When the circuit, loop, or relief vent connections are taken off the horizontal branch, the vent branch connection will be taken off at a vertical angle or from the top of the horizontal branch.

(4) Fixtures back-to-back in battery. When fixtures are connected to one horizontal branch through a double wye or a sanitary tee in a vertical position, a common vent will be provided for each two fixtures back-to-back or double connection. The common vent will be installed in a vertical position as a continuation of the double connections.

e. Size and Length of Main Vents. Vent stacks or main vents will have a diameter of at least 1/2 that of the soil or waste stack, and should be of larger diameter in accordance with the limits of length and number of fixtures units as given in table V. The length of the main vent should be the total developed length as follows:

(1) From the lowest connection of the vent system with the soil stack, waste stack, or primary branch to the terminal of the vent, if it terminates separately to the open air.

(2) From the lowest connection of the vent system with the soil stack, waste stack, or primary branch to the stack vent plus the developed length of the stack vent to its terminal in the open air, if the stack vent and vent stack are joined with a single extension to the open air.

Table V - Size and Length of Vents

Size of soil or waste stack	Fixture units con-nected	Diameter of vent required (inches)								
		1-1/4	1-1/2	2	2-1/2	3	4	5	6	8
		Maximum length of vent (feet)								
Inches										
1-1/4	2	30								
1-1/2	8	50	150							
1-1/2	10	30	100							
2	12	30	75	200						
2	20	26	50	150						
2-1/2	42	----	30	100	300					
3	10	----	30	100	200	600				
3	30	----	----	60	200	500				
3	60	----	----	50	80	400				
4	100	----	----	35	100	260	1000			
4	200	----	----	30	90	250	900			
4	500	----	----	20	70	180	700			
5	200	----	----	----	35	80	350	1000		
5	500	----	----	----	30	70	300	900		
5	1100	----	----	----	20	50	200	700		
6	350	----	----	----	25	50	200	400	1300	
6	620	----	----	----	15	30	125	300	1100	
6	960	----	----	----	----	24	100	250	1000	
6	1900	----	----	----	----	20	70	200	700	
8	600	----	----	----	----	----	50	150	500	1300
8	1400	----	----	----	----	----	40	100	400	1200
8	2200	----	----	----	----	----	30	80	350	1100
8	3600	----	----	----	----	----	25	60	250	800
10	1000	----	----	----	----	----	----	75	125	1000
10	2500	----	----	----	----	----	----	50	100	500
10	3800	----	----	----	----	----	----	30	80	350
10	5600	----	----	----	----	----	----	25	60	250

f. Storm Drains. Roofs and paved areas, yards, courts, and courtyards will be drained into the storm sewerage system or the combined sewerage system, but not into sewers intended for sanitary sewage only. When connected with a combined sewerage system, storm drains, the intakes of which are within 12 feet of any door, window, or ventilating opening, if not at least 3 feet higher than the top of such opening, will be effectively trapped. One trap on the main storm drain may serve for all such connections. Where there is no sewer accessible, storm drainage will discharge into an open trench unless otherwise permitted by the proper authorities, and in such case need not be trapped.

(1) Size of storm drains and leaders. Storm drains of a building must be of ample size to convey the estimated storm water from the roof gutters to the street sewer or other approved place of discharge without overflow and without producing dangerously high pressures in any building drain or leader. The estimated flow should be based on the maximum expected rate of rainfall and estimated rate of flow of storm sewage from other sources. The tables in this section pertaining to leaders and building storm drains are based on a rate of rainfall of 4 inches per hour and limited slopes as indicated in the tables.

(a) The area drained into or by a vertical leader or a sloping leader or connecting pipe having a slope of 1/2-inch fall per foot or greater should not exceed the values given in table VI.

Table VI - Maximum Roof Area for Leaders

Diameter of leader of pipe	Maximum roof area
Inches	Square feet
2	720
2-1/2	1300
3	2200
4	4600
5	8500
6	13,500
8	29,000

(b) The roof area drained into a building storm sewer or into a main storm drain or any of its branches should not exceed the values given in table VII.

Table VII - Maximum Roof Area for Building Storm Sewers or Drains

Diameter of pipe (inches)	Maximum roof area for drains of various slopes, square feet		
	1/8-inch fall per foot	1/4-inch fall per foot	1/2-inch fall per foot
	Square feet	Square feet	Square feet
2	--	350	500
3	822	1,160	1,644
4	1,880	2,650	3,760
5	3,340	4,720	6,680
6	5,350	7,550	10,700
8	11,500	16,300	23,000
10	20,700	29,200	41,400
12	33,300	47,000	66,600

(c) Roof area or drained area as applying in the preceding tables of this section should be the horizontal projection of the area, except that where a building wall extends above the roof or court in such a manner as to drain onto the roof or court, due allowance will be made for the additional runoff.

(2) Separate and combined drains. The sanitary and storm drainage systems of a building will be entirely separate, except that where a combined sanitary and storm street sewer is available, the storm drains may connect to a combined sanitary-and-storm building drain or sewer at least 10 feet downstream from any primary branch of the sanitary system. Connections between the sanitary and storm systems will be made at the same grade by means of a single wye fitting. Up to the point of combining into one system, the sizes of the storm and sanitary branches will be as required for

separate storm and sanitary systems and, where combined, the size will be proportionately increased.

(3) Closed system. When connected with a combined sanitary-and-storm sewerage system, the building storm-drainage piping will form a closed system with watertight joints, except for its outlet and intake openings.

(4) Overflow pipes from cisterns, supply tanks, expansion tanks, and drip pans will connect with any building sewer, building drain, or soil pipe only by means of an indirect connection.

(5) Subsoil sumps. Subsoil drains below the main-sewer level will discharge into a sump or receiver tank, the contents of which will be automatically lifted and discharged into the drainage system.

(6) Construction of subsoil drains. Where subsoil drains are placed under the cellar floor or used to encircle the outer walls of a building, they will be made of open-joint draintile or earthenware pipe not less than 4 inches in diameter. When the building drain is subject to backwater, the subsoil drain will be protected by an accessibly located automatic-back-pressure valve before entering the building sewer or drain. If such drains are connected with the sanitary sewer or with a combined system, they must be properly trapped. They may discharge to an area drain.

g. Indirect Connections to Waste Pipes. Waste pipes from the following will not connect directly with any building drain, soil, or waste pipe: Refrigerator, icebox, or other receptacle where food is stored; an appliance, device, or apparatus used in the preparation or processing of food or drink; an appliance, device, or apparatus using water as a cooling or heating medium; a sterilizer, water still, water-treatment device, or water-operated device. Such waste pipes will in all cases empty into and above the flood level of an open plumbing fixture. Indirect waste connections will not be located in inaccessible or unventilated cellars or other spaces.

2-07. TRAPS AND CLEANOUTS.

a. Grease Traps. Grease traps or interceptors should be

provided on the waste pipe from grease-disposing sinks or on the waste piping outside of buildings. Capacities of interceptors to be installed adjacent to fixtures will be in accordance with manufacturers' ratings and recommendations. Interceptors installed underground and outside of buildings will have a retention capacity of 1 gallon per person served by the kitchen. Each interceptor will be indicated in a location that will permit proper and complete removal of the grease.

b. Sand Interceptors. Sand interceptors when installed should be so designed and so placed as to separate sand and other materials and prevent such materials from entering the drainage system. Interceptors must be readily accessible for cleaning. Garage intercepting traps will be so arranged as to intercept all oils, gasoline, and other inflammable fluids, as well as sand and silt, for the purpose of excluding them from the public sewer system. Traps will be constructed of masonry, with a standard manhole frame and cover, at a depth of not less than 2 feet below the invert of the discharge drain, and with a net capacity of 6 cubic feet where the car-storage capacity exceeds three cars. Where the storage capacity exceeds three cars, 1 cubic foot in net capacity will be added for each additional car over three cars. When storage facilities are not maintained, as in the case of automobile repair shops, filling stations, service stations, etc., the capacity of the trap will be based upon a net capacity of 1 cubic foot of net capacity for each 100 square feet of surface to be discharged through the trap with a minimum net capacity of 6 cubic feet.

c. Types and Sizes of Traps. Every trap will be self-cleaning type, of the same nominal size as the drain to which it is connected, and must conform to accepted standards. Only P or drum traps are permitted. The size (nominal inside diameter) of trap and fixture drain for a given fixture will be the same as the size of the branch. (See table II on size of branch connections).

d. Traps Required. Each fixture will be separately trapped by an approved trap placed as near to the fixture as possible or integral therewith, except that a set of not more than three fixtures, such as lavatories or laundry trays, or a set of two laundry trays and one sink, may connect with a single trap provided they are not more than 3 inches apart.

e. Trap Cleanouts. Each fixture trap, except those in combination with fixtures in which the trap seal is readily accessible, will have trap screw of ample size protected by the water seal, or the top of the waste pipe will be not more than 1 inch below the top of the cleanout, except that when the bottom portion of a trap can be completely removed for cleaning purposes, no trap screw is required.

f. Pipe Cleanouts Required. Accessible cleanouts will be provided at or near the foot of each vertical waste or soil stack and each inside leader that connects to the building drain, and at each change in direction of the building drain greater than 45 degrees. The distance between cleanouts in horizontal soil lines will not exceed 50 feet. Cleanouts will be of the same nominal size as the pipes up to 4 inches and not less than 4 inches for larger pipes. Any fixture that can be removed may be regarded as a pipe cleanout.

2-08. WATER SUPPLY. Water-supply systems will conform to the following provisions:

a. Quality of Water Supply. The quality of the water supply for all premises intended for human occupancy will conform to the accepted standards of purity for potable water as established by the publication TB-MED-229 "Sanitary Control of Water Supplies for Fixed Installations" and the United States Public Health Service Drinking Water Standards. A water supply not conforming to accepted standards of purity for potable water, when used in an entirely separate system and when such use is specifically approved by proper administration authority, may be used for flushing water closets and urinals and for other purposes not requiring potable water; such water must not be readily accessible for drinking.

b. Protection of Water Supply. Potable and nonpotable water supplies will be distributed through systems entirely independent of each other, and any interconnections between such supplies is prohibited. Every supply outlet or connection to a fixture or appliance will be protected from backflow in accordance with the provisions of the American Standards Association or by an approved backflow preventer. Sterilization may be accomplished by introducing into the piping systems one of the chlorine compounds in amounts sufficient to give the water a chlorine dosage of 50 parts per million. The chlorinated water will be circulated throughout and allowed to remain in the entire system from

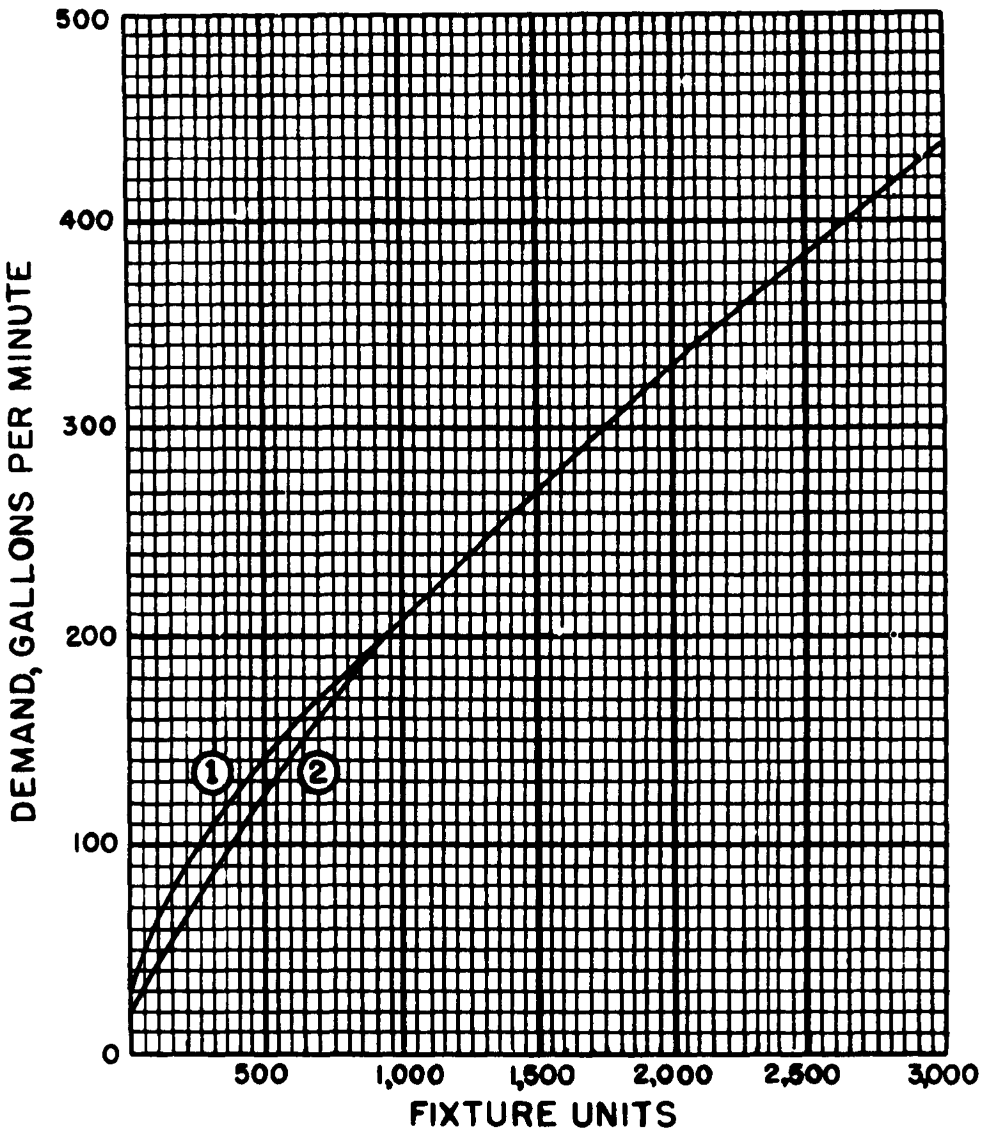
6 to 8 hours, after which the system will be thoroughly flushed with clean water.

c. Pumps, Wells, and Hydrants. All water pumps, tanks, wells, hydrants, filters, softeners, appliances, and devices will be protected from superficial ground or surface water and other contamination by approved covers, walls, copings, or casings.

d. Water-Supply Tanks. All nonpressure potable-water-supply tanks will be properly covered to prevent entrance of foreign material into the water supply. Soil or waste lines will not be permitted to pass directly over such tanks except on special approval by competent authority.

e. Protection Against Freezing. All water pipes, tanks, appliances, and devices subject to freezing temperature will be effectively protected against freezing.

f. Water Service. The water-service pipe will be of sufficient size to furnish an adequate flow of water to meet the requirements of the building at peak demand. The size of the water piping will be based on velocities limited to a maximum of 10 feet per second; and on such pressure loss that there will be a minimum pressure of 15 pounds per square inch at the highest fixture. A pressure-reducing valve will be provided if the pressure at the building main is more than 65 pounds per square inch. The following procedure is offered as a rational method of sizing the water-service and branch lines:



CURVE NO. 1 FOR SYSTEM WITH FLUSH VALVES
CURVE NO. 2 FOR SYSTEM WITH FLUSH TANKS

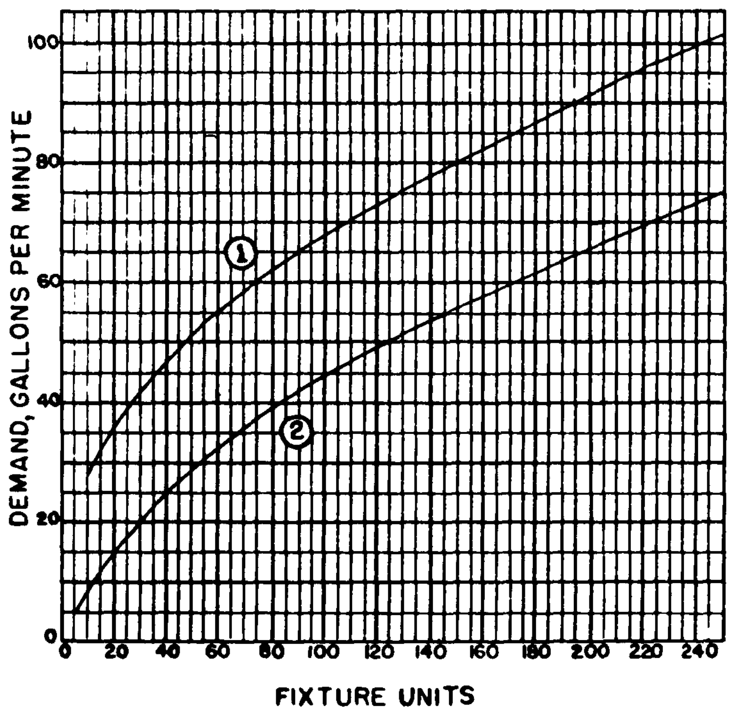
SUPPLY DEMAND CURVE

FOR USE WHEN FIXTURE UNITS ARE IN EXCESS OF 240

Figure I

Water service. From table I, list all the fixtures to be served, and opposite the fixtures, list the fixture units. Branch lines to fixtures for the hot-water branch and the same for the cold-water branch; example, one lavatory = two fixture units; hot-water branch = two x 3/4 = 1.5 fixture units, and the same for the cold-water branch.

g. Estimating Water Demand and Determining Pipe Sizes. The following procedure can be employed to determine the water requirements and the sizes of water-supply pipes:



CURVE NO. 1 FOR SYSTEM WITH FLUSH VALVES
CURVE NO. 2 FOR SYSTEM WITH FLUSH TANKS

SUPPLY DEMAND CURVE
FOR USE WITH 240 AND LESS FIXTURE UNITS

Figure 1A

(1) Tabulate the maximum and minimum water working pressures in the street main and the elevation of main at the building site.

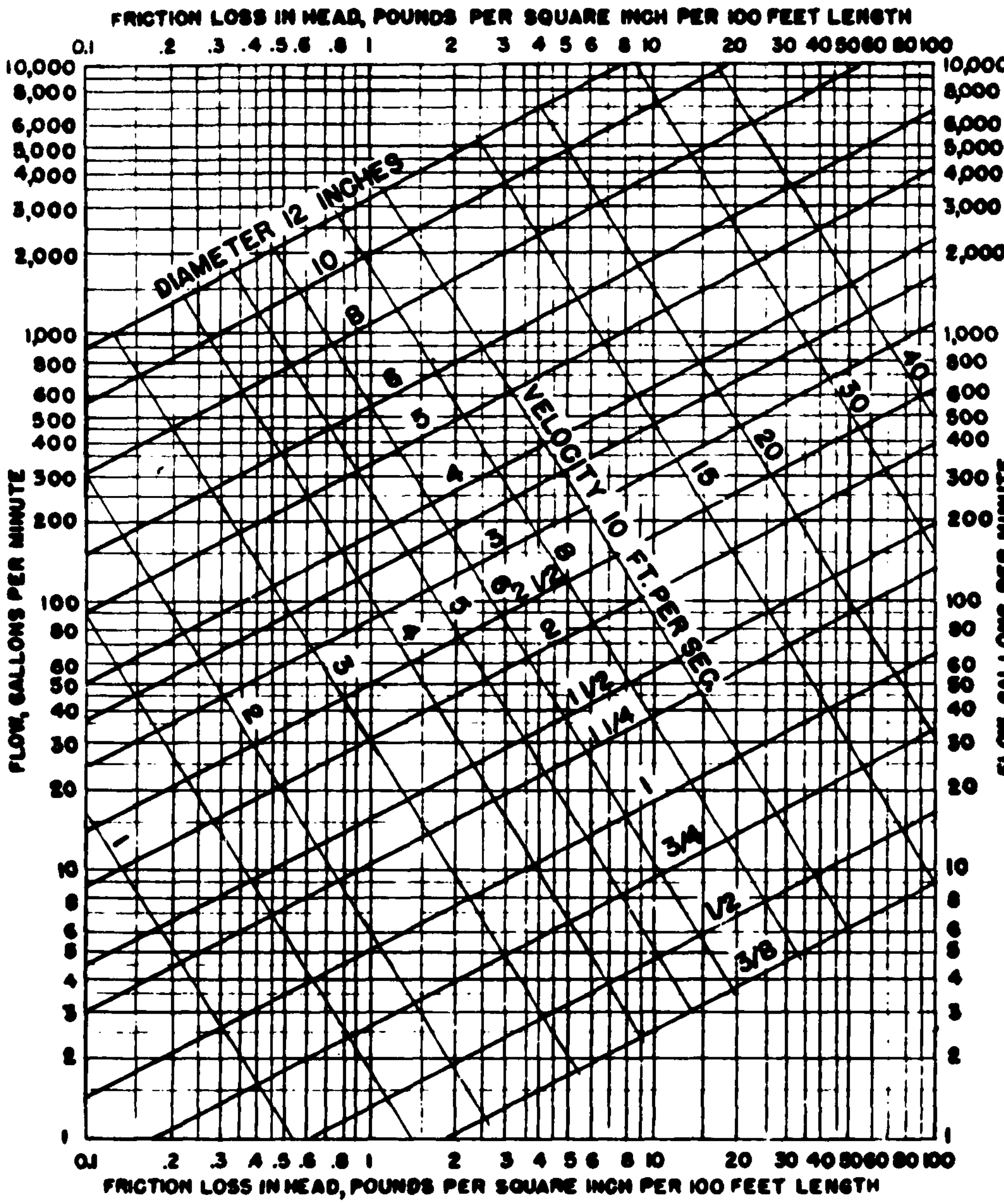
(2) Estimate supply demands based on fixture units from table II and read the corresponding ordinates from figure 1 or 1A.

(3) Pipe sizes can be determined from the flow chart, figure 2; velocities should not exceed 10 feet per second. The diameter of pipe on or next above the ordinate point corresponding to the estimated total demand and the permissible friction loss will be the size required.

(4) Fixture units in table II are for both hot- and cold-water demand. In sizing mains, branches, and risers, the following procedure will be followed:

For hot-water branches and risers, allow 3/4 of total fixture units assigned to fixtures requiring hot and cold water. For cold-water branches and risers, add fixture units assigned to fixture requiring cold water only to 3/4 of total fixture units assigned to fixture using hot and cold water. Mains can be determined by totaling fixture units assigned to fixtures or by deducting 1/3 of the units assigned to fixtures using hot and cold water and adding the results to the total fixture units assigned to fixtures using cold water. When the total fixture units include the fixtures using hot and cold water, then 1/3 of the fixture units assigned to the hot-water service will be added to the total to determine main sizes.

GRAPH IV



FLOW CHART FOR FAIRLY SMOOTH PIPE

FIGURE 2

(5) Total the water-supply requirements for fixtures and the requirements for mechanical equipment in the building.

(6) No building main will be less than 3/4 inch in diameter. If flush valves are installed, the minimum size of water service will be 1 inch.

(7) Allowances in equivalent lengths of pipe for friction loss in valves and threaded fittings will be added to the actual pipe length for determining the pressure drop or pipe size.

Example 1: A system has 100 fixture units, predominately flush valves. What is the probable demand in gallons of water per minute and the required pipe size?

Solution: Above 100 fixture units on figure 1, find 70 g.p.m. The pipe size is determined by reference to figure 2. Opposite 70 g.p.m., we find that 1-1/2-inch pipe would require a velocity of 12 feet per second. In accordance with the test, the velocity in feet per second should be less than 10. We note that a 2-inch pipe should be selected because it will deliver 70 g.p.m. at a velocity of 7 feet per second and a friction loss in head of 5 pounds per square inch per 100 feet in length.

Example 2: Plumbing fixtures within building consist of Toilet Room No. 1 with 2 water closets, 2 urinals, 2 lavatories, and 2 showers; Toilet Room No. 2 contains 2 water closets, 2 lavatories, 3 showers; Toilet Room No. 3 has 4 water closets, 2 urinals, and 5 lavatories; water pressure in the street main is 17 feet and a developed length of pipe from street main to the most distant fixture is 130 feet. Allow 15 pounds per square inch at the highest fixture. Water closets and urinals are equipped with flush valves. Urinals are wall-hung type.

Table VIII - Fixture Units

	Ea.	Total	CW	HW	g.p.m. CW	g.p.m. HW	Pipe Size Inch CW	Pipe Size Inch HW
Toilet Room No. 1								
2 Water Closets	10	20	20	--				
2 Urinals	5	10	10	--				
2 Lavatories	2	4	3	3				
2 Showers	4	8	6	6				
		42	39	9	48	8	1-1/2"	3/4"
Toilet Room No. 2								
2 Water Closets	10	20	20	--				
2 Lavatories	2	4	3	3				
3 Showers	4	12	9	9				
		36	32	12	42	10	1-1/2"	1"
Toilet Room No. 3								
4 Water Closets	10	40	40	--				
2 Urinals	5	10	10	--				
5 Lavatories	2	10	7.5	7.5				
		60	57.5	7.5	57	7	2"	3/4"
Total CW Fixture Units		138						
Total HW Fixture Units				28.5				

By reference to Figure 1A.

At 138 Fixture units the cold water demand will be 77 G.P.M.

At 28.5 Fixture units the hot water demand will be 19 G.P.M.

Minimum Service Pressure in lbs./sq. in.		30
Pressure loss p.s.i. due to elevation of fixtures (Height of highest outlet above street main in feet x 0.434)	0.434 x 17 =	7.4
Pressure required for operation of highest fixture, p.s.i.		15
Total pressure required for elevation and operation, p.s.i.		22.4
Pressure available for friction loss, p.s.i.	30 - 22.4 =	7.6
$\frac{\text{Pressure p.s.i. available for friction loss x 100 feet}}{\text{Developed length pipe, feet from street main to most distant fixture}}$ =	$\frac{7.6 \times 100}{130}$ =	6
Allowable friction loss p.s.i. for 100 feet of pipe		6
Building Service Main F.U. 138 G.P.M. 80	Pipe Size	2"
Hot Water Service F.U. 19 G.P.M. 20	Pipe Size	1-1/4"

2-09. HOT-WATER-SUPPLY SYSTEMS. Consideration will be given to the amount of water to be heated, the rate at which the water is to be heated, the range of temperature through which the water should be raised, the efficiency of heat transmission, and the heating medium of

hot-water-supply systems. The final temperature of the hot water will normally be 140 degrees F., except when hot water is required for sterilization of dishes; then the temperature of the water will be 180 degrees F. Where disturbed hospital patients have access to hot water, the final temperature will not exceed 100 degrees F.

2-10. SELECTION OF WATER-HEATING EQUIPMENT. The following information may be used as a guide in the selection of water-heating equipment:

a. Capacity. The capacity of coal- or gas-fired water heaters, based on a 100 degree F. rise in temperature, will be not less than 15 gallons per hour. Capacity of hot-water-storage tanks will be not less than 30 gallons per hour, except tanks in combination with the heater when the storage capacity will be not less than 20 gallons. Relief valves will be rated at a capacity in excess of the gross output of the water-heating equipment.

b. Water-Heater Types. When heaters are to be installed in locations where water contains a total of calcium and magnesium bicarbonate in an amount exceeding 200 parts per million and is expressed as calcium carbonate, consideration will be given to the use of a type of water heater that will not burn out or be subjected to rapidly decreasing efficiencies as a result of scale accumulation. Recommended heaters are those that are similar to the immersion-type water heater and have the heating surface similar to that of fire tubes in boilers which expel the scale by alternate expansion and contraction. Experience shows that some scaling of heaters may be encountered when the calcium and magnesium bicarbonates expressed as calcium carbonate are less than 200 parts per million. However, in these cases, central treatment of the water supply to the correct scale-forming conditions is desirable.

2-11. ESTIMATING HOT-WATER DEMAND. Methods prescribed for calculating water heaters and storage capacities for buildings are by the number of fixtures, and by the per-capita method. The temperature rise should be based on the water temperature of the local distribution system and the required delivery temperatures. The temperature rise is generally assumed to be 100 degrees F. The recovery capacity is defined as the hourly heating capacity in gallons raised to the required delivery temperature in degrees F. The per-capita method of deter-

mining the hot-water requirements is recommended when the number of persons assigned to a building is known. In buildings having an assigned population of less than 50 persons, the per-fixture method should be employed because the number of fixtures may be in excess of the recommended ratios of plumbing fixtures.

a. Hot-Water-Demand-Per-Fixture Method. The hot-water-demand per fixture for various types of buildings in gallons per hour should be determined by table IX.

Table IX - Hot-Water Demand per Fixture for Various Types of Buildings, Maximum Capacity, Gallons per Hour

Fixtures	Barracks	Hospital	Administrative	Industrial	Apartments	Quarters	Gym	Club
Bath tub	15	15			15	15	30	15
Laundry tub	35	35			25	35		25
Lavatories:								
Private	3	3	3	3	3	3		3
Public	10	10	8	12	5	5	10	10
Shower	150	100		250	100	100	250	200
Sink:								
Kitchen	20	20			10	20		20
Scullery	45	45						45
Service	30	20	30	20	20	20		30
Conversion factors:								
Heating	0.185	0.20	0.20	0.20	0.15	0.15	0.30	0.15
Storage	0.25	0.25	0.35	0.25	0.20	0.20	0.35	0.20

Example 3: Assume a barracks building has the following fixtures; determine the water-heating and storage requirements.

2 Laundry Tubs	x	35	-	70 g.p.h.
20 Lavatories	x	10	-	200 g.p.h.
4 Scullery sinks	x	45	-	180 g.p.h.
2 Service sinks	x	30	-	60 g.p.h.
12 Showers	x	150	-	1,800 g.p.h.
Maximum demand				2,310 g.p.h.

Hourly heating capacity $2,310 \times 0.185 = 427$ gallons, minimum

Storage capacity $2,310 \times 0.25 = 587$ gallons, minimum

The gallons of water to be heated per day per capita, the number of hours assumed for the duration of the average heating load, and the number of hours for peak hourly requirements, should conform with local conditions. The water-heating and storage requirements may be determined on the per-capita-day basis by the following equations.

$$A = \text{Average hourly heating capacity, gallons} = \frac{G \times N}{B}$$

$$P = \text{Peak hourly requirements, gallons} = \frac{G \times N}{D}$$

$$\text{Storage capacity, gallons} = \frac{P - A}{0.75}$$

Where G = Hot water required per day, per person, gallons
N = Number of persons assigned to building
B = Duration of average heating period, hours per day
D = Duration of peak load, hours per day
0.75 = 75% of hot water available from storage tank. Remainder of water in storage tank is assumed to be cool for satisfactory use.

b. Hot-Water-Demand-Per-Capita Method: Factors are tabulated in table X for determining minimum requirements for water heating and hot-water storage by the per-capita method. Duration of peak is assumed to be at not more than 2 consecutive hours with suitable interval for recovery.

Table X - Factors for Determining Minimum Requirements for Water Heating and for Hot-Water Storage, Per-Capita-Per-Day Method

Type of Buildings	Hot Water Per Person Per Day Gallons	Duration of Average Heating Period, Hours Per Day	Duration of Peak Load Hours Per Day
Administration, Office Buildings, Etc.	2	5	3
Barracks and Mess Halls	40	14	7
Barracks without Mess Halls	30	14	6
Hospitals	120[1]	20	10
Hotels	30	15	5
Industrial-Type Buildings	5	4	2
Mess Halls			
Hand Washing (Less Than 100 Persons)	10	8	3
Hand Washing (Over 100 Persons)	10	10	5
Machine Washing	10	10	5
Quarters and Apartments	40	8	4

[1] 120 Gallons per patient per day.

Example 4: Assume a barracks building without messhall will house 200 men. Refer to data in table X and the following equations; the capacity of the water-heating equipment and hot-water-storage tank may be determined as follows:

$$A = \text{Heating capacity} = \frac{30 \times 200}{14} = 428$$

$$P = \text{Peak hourly requirements} = \frac{30 \times 200}{6} = 1000$$

$$\text{Storage capacity} = \frac{1000 - 428}{0.75} = 762$$

Example 5: If the designer selects a tank having a storage capacity of 950 gallons; the heating capacity could be revised as follows:

$$\begin{aligned} \text{Revised heating capacity} &= \text{Peak} - (\text{Capacity of tank} \times 0.75) \\ &= 1000 - (950 \times 0.75) \\ &= 288 \text{ gallons per hour} \end{aligned}$$

If the designer should select a water heater having a capacity of 350 gallons per hour in lieu of the capacity indicated in the example, the storage capacity would be revised as follows:

$$\text{Revised storage capacity} = \frac{\text{Peak - selected heater capacity}}{0.75}$$

$$= \frac{1{,}000 - 350}{0.75}$$

$$= 815 \text{ gallons}$$

Example 6: Assume a hospital will be designed for 500 beds. Refer to the data in table X; the capacity of the water heating equipment may be determined as follows:

$$A = \text{Heating capacity} = \frac{500 \times 120}{20} = 3000 \text{ gallons per hour}$$

$$P = \text{Peak hourly requirements} = \frac{500 \times 120}{10} = 6000 \text{ gallons per hour}$$

$$\text{Storage capacity} = \frac{6{,}000 - 3{,}000}{0.75} = 4000 \text{ gallons}$$

c. Hot-Water Demand for Laundries. Hot-water demand for laundries should be based on the capacity of washers in pounds of dry clothes or the number of persons or patients to be served by the plant.

(1) Demand based on the capacity of the washers in pounds of dry clothes can be computed as follows:

$$\text{Total average requirements in gallons per hour} = R \times 5 \times 0.60$$

$$\text{Peak demand in gallons of water per minute} = \frac{R \times 5 \times 0.60}{3 \times F \times C}$$

Where R = Total rated capacity of washers, pounds of dry clothes
4 = Gallons of water per pound of dry clothes
0.60 = 60% of water to be heated
1/3 = That portion of the number of machines that may be filled simultaneously

F = Time required to fill each machine in minutes
C = Number of fill cycles per hour

(2) Demand based on number of patients or persons can be computed as follows:

$$\text{Total average in gallons per hour} = \frac{N \times P \times 5 \times 0.60}{H}$$

$$\text{Peak demand in gallons per minute} = \frac{N \times P \times 5 \times 0.60}{H \times 3 \times F \times C}$$

Where N = Number of patients or persons
P = Pounds of dry clothes per person or patient (15 pounds per person or 35 pounds per patient)
5 = Gallons per pound of dry clothes
0.60 = 60% of total water to be heated
H = Number of work hours per week
1/3 = That portion of the number of machines that may be filled simultaneously
F = Time required to fill each machine in minutes
C = Number of fill cycles per hour

Example 7: The capacity of the wash machines is 600 pounds of dry clothes. Find the total average hot-water requirements in gallons per hour and the peak hot-water demand in gallons per minute based on five operations per hour and assume that it will require 2 minutes to fill the washers.

Total average requirements in gallons per hour = 600 x 5 x 0.60 = 1,800

$$\text{Peak demand in gallons of water per minute} = \frac{600 \times 5 \times 0.60}{3 \times 2 \times 5} = 60$$

Example 8: A laundry will process clothes for 500 men in a 40-hour week. Assuming that it will require 2 minutes to fill each washer, determine the total average requirements in gallons of hot water per hour and the peak demand in gallons of water per minute.

$$\text{Total average in gallons per hour} = \frac{500 \times 15 \times 5 \times 0.60}{40} = 563$$

Peak demand in gallons of water per minute $= \frac{500 \times 15 \times 5 \times 0.60}{40 \times 3 \times 2 \times 5} = 19$

2-12. METHOD FOR DETERMINING HEATING SURFACE FOR COILS IN HOT-WATER GENERATORS. Conversion factors for determining the square feet of heating surface for hot-water generators with various steam pressures, for instantaneous water heaters and various boiler-water temperatures and various initial and final water temperatures are given in table XI.

Table XI - Conversion Factors for Determining the Square Feet of Heating Surface

Water Temperatures Degrees Fahrenheit		Hot Water Generators Steam Pressure, Pounds Per Square Inch, Gage							
From	To	0	5	10	15	25	40	50	100
50	100	.0135	.0119	.0114	.0103	.0106	.0087	.0081	.0069
	125	.0224	.0198	.0181	.0170	.0154	.0137	.0129	.0109
	150	.0347	.0298	.0270	.0251	.0222	.0198	.0188	.0154
	180	.0485	.0474	.0416	.0378	.0330	.0286	.0268	.0216
		Instantaneous Water Heaters Boiler Water Temperatures							
		210	200	180					
50	100	.0140	.0190	.0264					
	125	.0228	.0317	.0450					
	150	.0370	.0476	.0694					
	180	.0507	.0728	.1111					

Example 9: Determine the amount of heating surface required in a hot-water generator to heat 500 gallons of water per hour from 50 to 150 degrees F., with steam at 40 pounds pressure per square inch gage.

$500 \times 0.0198 = 9.9$ square feet of heating surface

2-13. DESIGN ANALYSIS. Design analysis will include fixture units for drainage and for cold- and hot-water piping. Roof areas will be indicated in connection with determination of storm-water-drainage-pipe sizes. The capacities of all equipment and tanks, and the itemized data used in determining capacities and sizes of plumbing facilities will be shown.

SECTION III - COMPRESSED AIR

3-01. TRADE STANDARDS. These criteria are based on the Trade Standards of the Compressed Air and Gas Institute.

3-02. TEST STANDARDS. To determine the performance of air compressors and blowers and/or to establish compliance with performance guaranties, tests are of value only if conducted carefully and in strict conformance with accepted methods and standards prescribed by the American Society of Mechanical Engineers Power Test Codes, for Centrifugal Compressors and for Displacement Compressors, Blowers, and Vacuum Pumps.

3-03. LOCATION OF AIR COMPRESSORS. Air compressors will be located in clean, well-lighted areas of sufficient size to permit cleaning, ready inspection, and any necessary dismantling, such as removal of pistons, wheels, crankshaft, or intercooler tube nest.

3-04. FOUNDATIONS. Drawings will be prepared for compressor foundations. To avoid transmission of vibration to the walls and floors of the room, the portion of the foundations that is below ground will be surrounded with 18 inches of coarse dry gravel, and the portion above ground separated from the floor around it by a narrow airgap or by vibration-insulation material such as asphalt.

3-05. AIR INTAKE.

a. Effect of Intake Temperature on Capacity. The intake of a compressor will be piped from outside the building, preferably on the north or coolest side. Since the density of air varies inversely as its temperature, an increase in delivery of approximately 1 percent is gained for every 5 degrees reduction in intake temperature as shown in table I.

Table I - Effect of Intake Temperature on Capacity

(Intake volume required to produce 1,000 cu. ft. of free air at 70° F.)

Temperature of intake, °F.	Relative intake volume required, cu. ft.	Percent hp saved	Temperature of intake, °F.	Relative intake volume required, cu. ft.	Percent hp saved
−50	773	22.7	40	943	5.7
−40	792	20.8	50	962	3.8
−30	811	18.9	60	981	1.9
−20	830	17.0	70	1,000	0
−10	849	15.1	80	1,019	−1.9
0	867	13.3	90	1,038	−3.8
10	886	11.4	100	1,057	−5.7
20	905	9.5	110	1,076	−7.6
30	925	7.5	120	1,095	−9.5

Example: If the indoor temperature is 70 degrees F. and the outdoor temperature 70 degrees F., and the compressor takes in 1,000 cubic feet of free air, it will deliver 1,000 cubic feet of free air because the initial and final temperatures are the same.

If the outside air is 40 degrees F. and the indoor temperature 70 degrees F., it will require an intake of only 943 cubic feet of the compressor air from outdoors to deliver 1,000 cubic feet of free air indoors, a direct saving of 5.7 percent. The cooler the climate, the more pronounced the effect becomes.

b. Air Filters. Dirt and grit are always present in the atmosphere, and if sucked into the compressor will cause wear of the working parts. An efficient air cleaner will be used on the intake of every air compressor. Filters may be dry type or oil-bath type. Air intakes will be located as far as possible from ash or coal bins and never near a steam-exhaust head or fan outlet from a paint-spray booth.

3-06. AIR-DISCHARGE PIPE. The discharge pipe will not be smaller than the full size of compressor outlet and will run directly to the aftercooler or air receiver. Piping connected to the compressor will be arranged with flanged fittings or unions close to the compressor to permit removal of the cylinder at any time without disturbing the piping. Overhead piping will be well supported to relieve the cylinders of incidental strains. The discharge pipe will be as short and direct as possible, with a minimum of fittings and with long-radius elbows where bends are necessary.

3-07. CIRCULATING WATER. A liberal supply of cooling water for cylinder jackets, cylinder heads, intercoolers, and aftercoolers will be provided and the water supply will be turned on before the compressor is started. Where the cooling water is very cold, condensation may form in the air-inlet passage of the high-pressure cylinder as the air passes through in coming from the intercooler, because the air may be much warmer than the water. If condensation forms, it will be carried into the air cylinder and destroy the lubricant, causing rapid cylinder and valve wear. To relieve this condition, it is advisable to pass the cold water through the intercooler first to increase its temperature before going to the cylinder jackets, or to reduce the supply to the cylinder jackets so that the temperature of the discharge therefrom will be between 100 degrees and 115 degrees F. With the amounts of cooling water given in table II, it is expected that the temperature of the air leaving the intercooler or aftercooler will be within 20 and 15 degrees respectively of the temperature of the water entering the cooler for ordinary working conditions.

Table II - Cooling Water Recommended for Intercoolers, Cylinder Jackets and Aftercoolers

	Gallons of water per hundred cu. ft. actual free air
Intercooler Separate	2.5 to 2.8
Intercooler and Jackets in Series	2.5 to 2.8
Aftercoolers:	
80–100 lbs. Two-Stage	1.25
80–100 lbs. Single-Stage	1.8
Two-Stage Jackets alone (both)	.8
Single-Stage Jackets:	
40 lbs	.6
60 lbs	.8
80 lbs	1.1
100 lbs	1.3

3-08. PIPING. Compressed-air piping will be indicated parallel with the lines of the building. Traps will be inserted in air lines at frequent intervals to remove condensed moisture. Automatic moisture traps are available for this purpose, or traps may be used that are made of pipe and fittings consisting of tees having a pipe leg hanging down with a drain connected at the bottom. Traps are effective only when the air has been cooled and the moisture has precipitated. Where the air is not allowed to stand unused for any period of time and where there is little opportunity for the air to cool by radiation, an after-

cooler will be used to cool the air so that its moisture can be precipitated and removed. If an aftercooler is not employed, much of the trouble experienced with water in air lines can be overcome if small air receivers are put in the lines at frequent intervals to act as collecting tanks. Branches from compressed-air mains will be taken off at the top to avoid picking up moisture. When a gate or globe valve is placed in the discharge line between the compressor and aftercooler or receiver, a safety valve will be placed in the pipeline between the cylinder and the shutoff valve. The safety valve or valves will have a total capacity sufficient to handle the entire output of the compressor. If no safety valve is used and the stop valve is closed upon starting, sufficient pressure may be built up to burst the cylinder. On those installations where there are many branch outlets a great distance from the compressor, it is suggested that the discharge piping be installed in a loop system so that the pressure will be approximately equal at all branches.

a. Loss of Air Pressure Due to Friction. The loss of pressure in piping is caused by resistance in the pipe itself, resistance in fittings and valves that dissipate energy by producing large-scale turbulences, and many other factors. The piping system will be designed for a maximum allowable drop in pressure of 10 percent from compressor to point of discharge. The tables and graphs included herein apply to steel or wrought-iron pipe only. All data are based on nonpulsating flow and apply to clean and smooth pipe. Graph I and tables V to VIII inclusive, are calculated from the following formula by Professor E. G. Harris, University of Missouri:

$$p = \frac{c\,L}{r} \times \frac{Q^2}{d^5}$$

$$c = \frac{0.1025}{d^{0.31}} = \text{Coefficient for ordinary pipe}$$

$$\text{Therefore} \quad p = \frac{0.1025L}{r} \times \frac{Q^2}{d^{5.31}}$$

Where p = Pressure drop due to friction, pounds per square inch.
L = Length of pipe, feet.
Q = Rate of flow of free air, cubic feet per second.

r = Ratio of compression (referred to atmosphere) at entrance of pipe.
d = Actual internal diameter of pipe, inches.
c = Experimental coefficient.

The above equations can be further simplified to the following formula (1):

$$\text{Then } p = \frac{Q^2 \times F}{P}$$

Where p = Pressure drop due to friction per 100 feet of pipe, pounds per square inch.
Q = Rate of flow of free air, cubic feet per minute.
P = Initial pressure at the entrance to the pipe, pounds per square inch absolute.
F = Factor, which is a function of inside diameter of the pipe (d in inches), combined with the formula constant.

$$\text{Its value is } \frac{0.04185}{d^{5.31}}$$

To facilitate the use of the formula, values of F for nominal pipe sizes are tabulated in table III.

Table III - Numerical Values of Factor F[1]

Nominal pipe size, inches	Standard weight pipe	Extra strong pipe
1¼	7.568×10^{-3}	11.375×10^{-3}
1½	3.337×10^{-3}	4.860×10^{-3}
2	885.5×10^{-6}	1.244×10^{-3}
2½	344.7×10^{-6}	476.4×10^{-6}
3	108.7×10^{-6}	146.7×10^{-6}
3½	50.27×10^{-6}	66.89×10^{-6}
4	25.70×10^{-6}	33.67×10^{-6}
5	7.737×10^{-6}	9.955×10^{-6}
6	2.914×10^{-6}	3.832×10^{-6}
8	678.8×10^{-9}	865.0×10^{-9}
10	202.8×10^{-9}	260.0×10^{-9}
12	80.04×10^{-9}	103.6×10^{-9}

[1] Factors are valid for schedule 40 wrought steel and wrought-iron pipe only.

Figure I gives the pressure drop in pipes up to 12 inches in diameter, for capacities up to 10,000 cubic feet of free air per minute, and for initial pressures up to 400 pounds per square inch.

Tables V through VIII, inclusive, show the pressure drop in pipes to 6 inches in diameter, for capacities up to 1,000 cubic feet of free air per minute, and for initial pressures of 60, 80, 100, and 125 pounds per square inch.

For longer or shorter lengths of pipe, the friction loss is proportional to the lengths; that is, for 500 feet, one-half of the above; for 4,000 feet, four times the above, etc. For initial pressures and pipe sizes not included in the figure and tables, formula (1) will be used. To calculate the pressure drop in pipe other than wrought steel or wrought iron, the principles of fluid dynamics will be employed; such principles are too involved to be included in the scope of this manual.

LOSS OF AIR PRESSURE IN PIPING DUE TO FRICTION

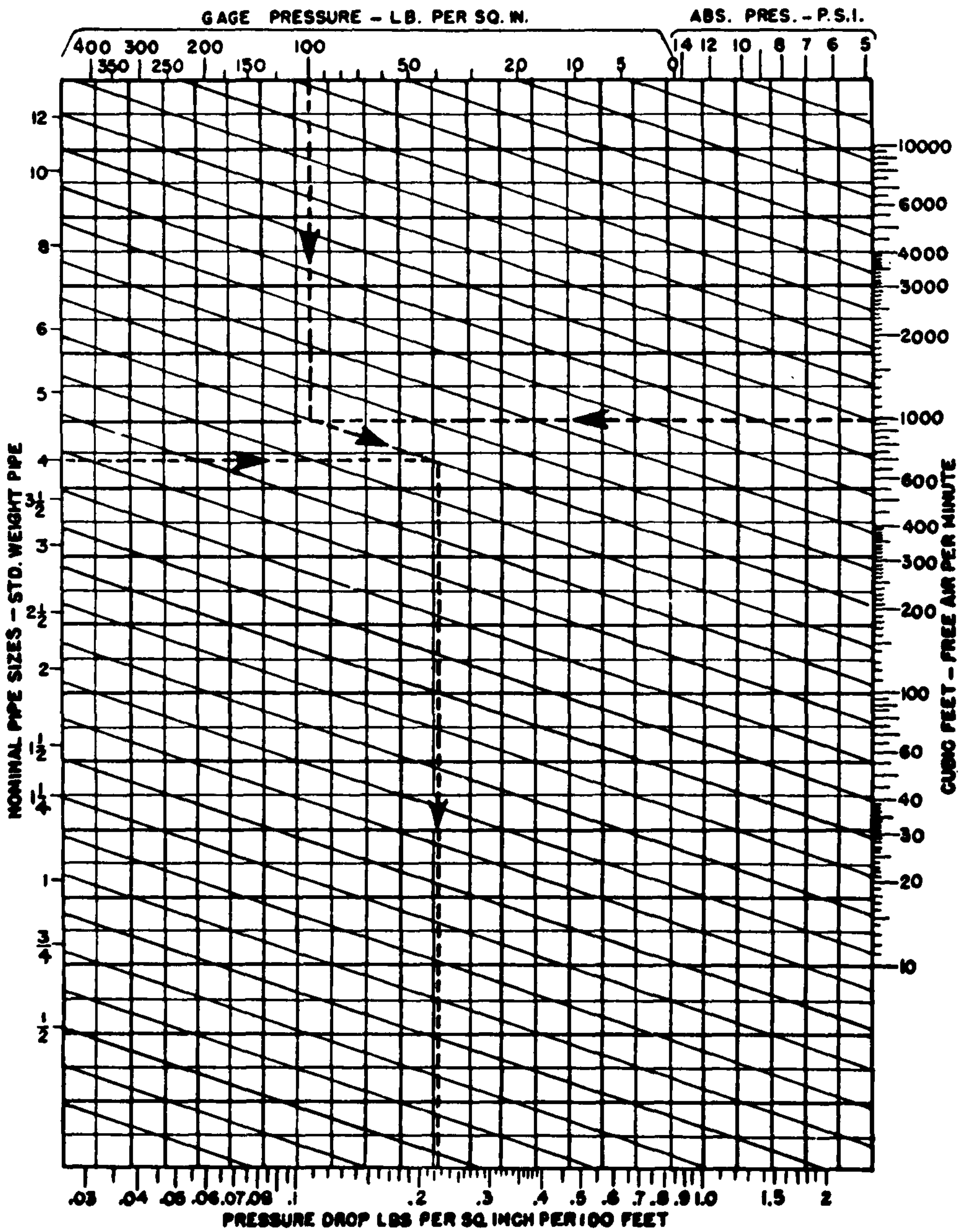


FIGURE 1

The addition of valves and fittings to the piping system will add a considerable amount of friction. Table IV gives the value of the loss of pressure through screwed pipe fittings, expressed in equivalent lengths of straight pipe. These lengths will be added to the length of pipe before using the figure and tables.

Table IV - Loss of Pressure Through Screw Pipe Fittings

[Given in equivalent lengths (feet) of straight pipe]

Nominal pipe size (in.)	Actual inside diameter (in.)	Gate valve	Long radius ell or on run of standard tee	Standard ell or on run of tee reduced in size 50 percent	Angle valve	Close return bend	Tee through side outlet	Globe valve
½	0.622	0.36	0.62	1.55	8.65	3.47	3.10	17.3
¾	.824	.48	.82	2.06	11.4	4.60	4.12	22.9
1	1.049	.61	1.05	2.62	14.6	5.82	5.24	29.1
1¼	1.380	.81	1.38	3.45	19.1	7.66	6.90	38.3
1½	1.610	.94	1.61	4.02	22.4	8.95	8.04	44.7
2	2.067	1.21	2.07	5.17	28.7	11.5	10.3	57.4
2½	2.469	1.44	2.47	6.16	34.3	13.7	12.3	68.5
3	3.068	1.79	3.07	6.16	42.6	17.1	15.3	85.2
4	4.026	2.35	4.03	7.67	56.0	22.4	20.2	112.0
5	5.047	2.94	5.05	10.1	70.0	28.0	25.2	140.0
6	6.065	3.54	6.07	15.2	84.1	33.8	30.4	168.0
8	7.981	4.65	7.98	20.0	111.0	44.6	40.0	222.0
10	10.020	5.85	10.00	25.0	139.0	55.7	50.0	278.0
12	11.940	6.96	11.00	29.8	166.00	66.3	59.6	332.0

Example 1: One thousand cubic feet of free air per minute are to be transmitted at 100 pounds per square inch gage pressure through a 4-inch standard-weight steel pipe. What will be the pressure drop due to friction?

Solution: Enter figure 1 at the top at the point representing 100 pounds per square inch gage pressure and proceed vertically downward to the intersection with a horizontal line representing 1,000 c.f.m., then parallel to the diagonal guidelines to the right (or left) to the intersection with a horizontal line representing a 4-inch pipe, then vertically downward to the pressure-loss scale at the bottom of the graph, where it is observed that the pressure loss would be 0.225 pound per square inch per 100 feet of pipe.

Example 2: One hundred fifty cubic feet of free air per minute at 125 pounds per square inch pressure is to be distributed through 500 feet of 1-1/4-inch galvanized steel pipe which contains two globe valves and six standard elbows. What will be the pressure drop due to friction?

Solution: Table IV indicates that the pressure loss in a 1-1/4-inch globe valve is equivalent to 38.3 feet of straight 1-1/4-inch pipe and the loss for a standard elbow is equivalent to 3.45 feet of 1-1/4-inch pipe. Since there are two valves and six elbows, the total equivalent length of pipe due to the fittings is equal to 97.3 feet. The total length of pipe in the distribution system, therefore, is equal to 500 plus 97.3 feet or 597.3 feet. From table VIII, the loss in 1,000 feet of 1-1/4-inch pipe for a flow of 150 cubic feet of free air per minute, is 12 pounds per square inch. Multiplying this factor by 597.3 and dividing by 1,000 gives a pressure loss of 7.2 pounds per square inch or a terminal gage reading of 117.8 pounds per square inch.

Table V - Loss of Air Pressure Due to Friction, Pounds per Square Inch in 1,000 Feet of Pipe, 60 Pounds Gage Initial Pressure

Free air, cu ft. per min.	Equivalent compressed air, cu. ft. per min.	Nominal diameter, inches												
		½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6
10	1.96	10.0	1.53	0.43	0.10									
20	3.94	39.7	5.99	1.71	.39	0.18								
30	5.89	89.7	13.85	3.86	.88	.40								
40	7.86		24.7	6.85	1.59	.71	0.19							
50	9.84		38.6	10.7	2.48	1.10	.30							
60	11.81		55.5	15.4	3.58	1.57	.43							
70	13.75		75.8	21.0	4.87	2.15	.57	0.22						
80	15.72		99.0	27.4	6.37	2.82	.75	.29						
90	17.65			34.7	8.05	3.57	.95	.37						
100	19.60			42.8	9.95	4.40	1.18	.46						
125	24.60			67.0	15.7	6.90	1.83	.71	0.14					
150	29.45			96.4	22.4	9.90	2.64	1.02	.32	0.15				
175	34.44				30.8	13.40	3.64	1.40	.43	.20				
200	39.40				39.7	17.60	4.71	1.83	.57	.27				
250	49.20				62.8	27.5	7.37	2.85	.89	.42	0.21			
300	58.90				89.3	39.6	10.55	4.11	1.50	.60	.31			
350	68.8					54.0	14.4	5.60	1.76	.82	.42	0.23		
400	78.8					70.4	18.6	7.30	2.30	1.06	.53	.30		
450	88.4					89.1	23.7	9.20	2.90	1.35	.70	.38		
500	98.4						29.7	11.4	3.60	1.67	.85	.46	0.26	
600	118.1						42.3	16.4	5.17	2.40	1.22	.67	.37	
700	137.5						57.8	22.3	7.00	3.27	1.67	.91	.50	0.19
800	157.2						75.2	29.2	9.16	4.26	2.18	1.20	.65	.25
900	176.5						95.5	37.0	11.6	5.40	2.76	1.51	.83	.31
1,000	196.0							45.7	14.3	6.65	3.40	1.87	1.02	.39

Table VI - Loss of Air Pressure Due to Friction, Pounds per Square Inch in 1,000 Feet of Pipe, 80 Pounds Gage Initial Pressure

Free air, cu. ft. per min.	Equivalent compressed air, cu. ft. per min.	Nominal diameter, inches												
		½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6
10	1.55	7.90	1.21	0.34										
20	3.10	31.4	4.72	1.35	0.31									
30	4.65	70.8	10.9	3.05	.69	0.31								
40	6.20	-----	19.5	5.40	1.25	.56								
50	7.74	-----	30.5	8.45	1.96	.87								
60	9.29	-----	43.8	12.16	2.82	1.24	0.34							
70	10.82	-----	59.8	16.6	3.84	1.70	.45							
80	12.40	-----	78.2	21.6	5.03	2.22	.59							
90	13.95	-----	-----	27.4	6.35	2.82	.75							
100	15.5	-----	-----	33.8	7.85	3.47	.93	0.36						
125	19.4	-----	-----	46.2	12.4	5.45	1.44	.56						
150	23.2	-----	-----	76.2	17.7	7.82	2.08	.81						
175	27.2	-----	-----	-----	24.8	10.6	2.87	1.10						
200	31.0	-----	-----	-----	31.4	13.9	3.72	1.44	0.45					
250	38.7	-----	-----	-----	49.0	21.7	5.82	2.25	.70	0.33				
300	46.5	-----	-----	-----	70.6	31.2	8.35	3.24	1.03	.47				
350	54.2	-----	-----	-----	96.0	42.5	11.4	4.42	1.39	.65	0.33			
400	62.0	-----	-----	-----	-----	55.5	14.7	5.76	1.82	.84	.42			
450	69.7	-----	-----	-----	-----	70.2	18.7	7.25	2.29	1.06	.55			
500	77.4	-----	-----	-----	-----	86.7	23.3	9.0	2.84	1.32	.67	0.30		
600	92.9	-----	-----	-----	-----	-----	33.4	12.9	4.08	1.89	.96	.53		
700	108.2	-----	-----	-----	-----	-----	45.7	17.6	5.52	2.58	1.32	.72	0.40	
800	124.0	-----	-----	-----	-----	-----	59.3	23.1	7.15	3.36	1.72	.95	.51	
900	139.5	-----	-----	-----	-----	-----	75.5	29.2	9.17	4.26	2.18	1.19	.65	
1,000	155.0	-----	-----	-----	-----	-----	93.2	36.1	11.3	5.27	2.68	1.48	.81	0.30

Table VII - Loss of Air Pressure Due to Friction, Pounds per Square Inch in 1,000 Feet of Pipe, 100 Pounds Gage Initial Pressure

Free air, cu. ft. per min.	Equivalent compressed air, cu. ft. per min	Nominal diameter, inches												
		½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6
10	1.28	6.50	0.99	0.28										
20	2.56	25.9	3.90	1.11	0.25	0.11								
30	3.84	58.5	9.01	2.51	.57	.26								
40	5.12	-----	16.0	4.45	1.03	.46								
50	6.41	-----	25.1	6.96	1.61	.71	0.19							
60	7.68	-----	36.2	10.0	2.32	1.02	.28							
70	8.96	-----	49.3	13.7	3.16	1.40	.37							
80	10.24	-----	64.5	17.8	4.14	1.83	.49	0.19						
90	11.52	-----	82.8	22.6	5.23	2.32	.62	.24						
100	12.81	-----	-----	27.9	6.47	2.86	.77	.30						
125	15.82	-----	-----	48.6	10.2	4.49	1.19	.46						
150	19.23	-----	-----	62.8	14.6	6.43	1.72	.66	0.21					
175	22.40	-----	-----	-----	19.8	8.72	2.36	.91	.28					
200	25.62	-----	-----	-----	25.9	11.4	3.06	1.19	.37	0.17				
250	31.64	-----	-----	-----	40.4	17.9	4.78	1.85	.58	.27				
300	38.44	-----	-----	-----	58.2	25.8	6.85	2.67	.84	.39	0.20			
350	44.80	-----	-----	-----	-----	35.1	9.36	3.64	1.14	.53	.27			
400	51.24	-----	-----	-----	-----	45.8	12.1	4.75	1.50	.69	.35	0.19		
450	57.65	-----	-----	-----	-----	58.0	15.4	5.98	1.89	.88	.46	.25		
500	63.28	-----	-----	-----	-----	71.6	19.2	7.42	2.34	1.09	.55	.30	0.17	
600	76.88	-----	-----	-----	-----	-----	27.6	10.7	3.36	1.56	.79	.44	.24	
700	89.6	-----	-----	-----	-----	-----	37.7	14.5	4.55	2.13	1.09	.59	.33	
800	102.5	-----	-----	-----	-----	-----	49.0	19.0	5.89	2.77	1.42	.78	.42	
900	115.3	-----	-----	-----	-----	-----	62.3	24.1	7.6	3.51	1.80	.99	.54	0.20
1,000	126.6	-----	-----	-----	-----	-----	76.9	29.8	9.3	4.35	2.21	1.22	.66	.25

Table VIII - Loss of Air Pressure Due to Friction, Pounds per Square Inch in 1,000 Feet of Pipe, 125 Pounds Gage Initial Pressure

Free air, cu. ft. per min.	Equivalent compressed air, cu. ft. per min.	Nominal diameter, inches												
		½	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6
10	1.05	5.35	0.82	0.23										
20	2.11	21.3	3.21	.92	0.21									
30	3.16	48.0	7.42	2.07	.47	0.21								
40	4.21	-----	13.2	3.67	.85	.38								
50	5.26	-----	20.6	5.72	1.33	.59								
60	6.32	-----	29.7	8.25	1.86	.84	0.23							
70	7.38	-----	40.5	11.2	2.61	1.15	.31							
80	8.42	-----	53.0	14.7	3.41	1.51	.40							
90	9.47	-----	68.0	18.6	4.30	1.91	.51	0.20						
100	10.50	-----	-----	22.9	5.32	2.36	.63	.25						
125	13.15	-----	-----	39.9	8.4	3.70	.98	.38						
150	15.79	-----	-----	51.6	12.0	5.30	1.41	.55	0.17					
175	18.41	-----	-----	-----	16.3	7.2	1.95	.75	.24					
200	21.05	-----	-----	-----	21.3	9.4	2.52	.98	.31					
250	26.30	-----	-----	-----	33.2	14.7	3.94	1.53	.48	0.22				
300	31.60	-----	-----	-----	47.3	21.2	5.62	2.20	.70	.32				
350	36.80	-----	-----	-----	-----	28.8	7.7	3.00	.94	.44	0.22			
400	42.10	-----	-----	-----	-----	37.6	10.0	3.91	1.23	.57	.28			
450	47.30	-----	-----	-----	-----	47.7	12.7	4.92	1.55	.72	.37	0.20		
500	52.60	-----	-----	-----	-----	58.8	15.7	6.10	1.93	.89	.46	.25		
600	63.20	-----	-----	-----	-----	-----	22.6	8.8	2.76	1.28	.65	.36	0.20	
700	73.80	-----	-----	-----	-----	-----	30.0	11.9	3.74	1.75	.89	.49	.27	
800	84.20	-----	-----	-----	-----	-----	40.2	15.6	4.85	2.28	1.17	.64	.35	
900	94.70	-----	-----	-----	-----	-----	51.2	19.8	6.2	2.89	1.48	.81	.44	
1,000	105.1	-----	-----	-----	-----	-----	63.2	24.5	7.7	3.57	1.82	1.00	.55	0.21

b. Flow of Compressed Air in Pipes. In considering the flow of compressed air in pipes, solve for the value of Q, volume in cubic feet per minute from formula (1) as follows:

$$Q = \frac{p \times P}{F}$$

c. Air Consumption. The air consumption for various tools and equipment expressed in cubic feet of free air per minute is listed in tables IX and X. Compressed-air requirements for laundry and dry-cleaning equipment are listed in reference 3d. Discharge of air through orifices, indicated in cubic feet of air per minute measured at absolute pressure of 14.7 pounds per square inch and 70 degrees F., is listed in table XI. Multipliers for determining volumes of air compressed and

delivered at various pressures when capacities are expressed in cubic feet of free air at atmosphere pressure and at constant temperature are listed in table XII.

Table IX - Air Consumption of Shop Tools and Equipment

Tools or equipment	Size or type	Air pressure (pounds per sq. in.)	Air consumed (cu. ft. of free air per min.)
Blow gun		70–90	3
Bus or truck lift		70–90	10
Car lift		70–90	6
Car rocker		70–90	6
Drills, rotary	Weight 10 lbs.	70–90	15
Engine, cleaning		70–90	5
Grease gun		70–90	4
Grinders, hand	Weight 17 lbs.	70–90	20
Grinders, hand	Weight 24 lbs.	70–90	30
Paint sprays	Production gun	40–70	20
Paint sprays	Touch up gun	40–70	30
Paint sprays	Small hand	70–90	2–7
Riveters, hand	Weight 13 lbs.	70–90	18
Riveting machines	Reach 12–30	70–90	5
Riveting machines	Reach 36–45	70–90	6½
Spring oiler		70–90	3
Surfacers	Weight 35 lbs.	70–90	30–40
Surfacers	Weight 65 lbs.	70–90	60–70
Tire changer		70–90	½
Tire inflater		70–90	1½
Tire spreader		70–90	½
Valve grinder		70–90	2

Table X - Air Requirements for Pneumatic Pumping Systems

Pump capacity, g. p. m.	Compressed air required, cu. ft. of free air per min.
25	1. 5
45	2. 5
80	4. 5
150	7. 5
170	11. 0

Table XI - Discharge of Air Through Orifice

[Cubic feet of air per minute measured at absolute pressure of 14.7 pounds per square inch and 70° F.]

Gage pressure before orifice, pounds per sq. in.	Diameter of orifice, inches										
	1/64	1/32	1/16	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
	Discharge of free air, cubic feet per minute										
1	0.028	0.112	0.450	1.80	7.18	16.2	28.7	45.0	64.7	88.1	115
2	.040	.158	.633	2.53	10.1	22.8	40.5	63.3	91.2	124	162
3	.048	.194	.775	3.10	12.4	27.8	49.5	77.5	111	152	198
4	.056	.223	.892	3.56	14.3	32.1	57.0	89.2	128	175	228
5	.062	.248	.993	3.97	15.9	35.7	63.5	99.3	143	195	254
6	.068	.272	1.09	4.34	17.4	39.1	69.5	109	156	213	278
7	.073	.293	1.17	4.68	18.7	42.2	75.0	117	168	230	300
9	.083	.331	1.32	5.30	21.2	47.7	84.7	132	191	260	339
12	.095	.379	1.52	6.07	24.3	54.6	97.0	152	218	297	388
15	.105	.420	1.68	6.72	26.9	60.5	108	168	242	329	430
20	.123	.491	1.96	7.86	31.4	70.7	126	196	283	385	503
25	.140	.562	2.25	8.98	35.9	80.9	144	225	323	440	575
30	.158	.633	2.53	10.1	40.5	91.1	162	253	365	496	648
35	.176	.703	2.81	11.3	45.0	101	180	281	405	551	720
40	.194	.774	3.10	12.4	49.6	112	198	310	446	607	793
45	.211	.845	3.38	13.5	54.1	122	216	338	487	662	865
50	.229	.916	3.66	14.7	58.6	132	235	366	528	718	938
60	.264	1.06	4.23	16.9	67.6	152	271	423	609	828	1,082
70	.300	1.20	4.79	19.2	76.7	173	307	479	690	939	1,227
80	.335	1.34	5.36	21.4	85.7	193	343	536	771	1,050	1,371
90	.370	1.48	5.92	23.7	94.8	213	379	592	853	1,161	1,516
100	.406	1.62	6.49	26.0	104	234	415	649	934	1,272	1,661
110	.441	1.76	7.05	28.2	113	254	452	705	1,016	1,383	1,806
120	.476	1.91	7.62	30.5	122	274	488	762	1,097	1,494	1,951
125	.494	1.98	7.90	31.6	126	284	506	790	1,138	1,549	2,023

Table is based on 100 percent coefficient of flow. For well-rounded entrance, multiply values by 0.97; for sharp-edged orifices, multiply by 0.65.

Table XII - Multipliers for Determining Volumes of Air Compressed and Delivered at Various Pressures When Capacities Are Expressed in Cubic Feet of Free Air at Atmospheric Pressure and at Constant Temperature

Pressure	Multiplier	Pressure	Multiplier	Pressure	Multiplier	Pressure	Multiplier
Pounds		*Pounds*		*Pounds*		*Pounds*	
1	0.9363	26	0.3612	51	0.2237	76	0.1621
2	.8802	27	.3525	52	.2204	77	.1603
3	.8305	28	.3443	53	.2171	78	.1586
4	.7861	29	.3364	54	.2140	79	.1569
5	.7462	30	.3289	55	.2109	80	.1552
6	.7101	31	.3217	56	.2079	81	.1536
7	.6774	32	.3148	57	.2050	82	.1520
8	.6476	33	.3082	58	.2022	83	.1505
9	.6203	34	.3018	59	.1995	84	.1489
10	.5951	35	.2958	60	.1968	85	.1474
11	.5720	36	.2899	61	.1942	86	.1460
12	.5506	37	.2843	62	.1917	87	.1445
13	.5307	38	.2789	63	.1892	88	.1431
14	.5122	39	.2737	64	.1868	89	.1418
15	.4949	40	.2687	65	.1844	90	.1404
16	.4788	41	.2639	66	.1822	91	.1391
17	.4637	42	.2593	67	.1799	92	.1378
18	.4495	43	.2548	68	.1778	93	.1365
19	.4362	44	.2504	69	.1756	94	.1352
20	.4236	45	.2462	70	.1736	95	.1340
21	.4118	46	.2422	71	.1715	96	.1328
22	.4005	47	.2382	72	.1696	97	.1316
23	.3899	48	.2344	73	.1676	98	.1304
24	.3798	49	.2308	74	.1657	99	.1293
25	.3703	50	.2272	75	.1639	100	.1282

Example 3: One hundred cubic feet of free air represents the output of the compressor at atmospheric pressure. What will be the output of the compressor when the air is compressed and delivered at 70 p.s.i. at constant temperature?

The multiplier for pressure at 70 p.s.i. is 0.1736.

Therefore, 100 x 0.1736 = 17.36 cubic feet.

3-09. AIR RECEIVER. The air receiver or tank will be placed as close to the compressor as possible in order to keep the discharge pipe short. The receiver will be provided with a drain cock near the bottom and will be drained from time to time. The receiver will also be provided with a safety valve that will be tested occasionally by lifting the lever or raising the pressure to that required to operate the valve.

Table XIII - A. S. M. E. Standard Air Receivers

Size		Actual compressor capacity for which receiver is suited, cu. ft. free air per minute [1]	Volume, cubic feet	Safety valves		Size of drain valves	Types of opening for cleaning
Diameter (inches)	Length (feet)			Number	Diameter (inches)		
14	4	60	4½	1	¾	Size of drain should meet requirements of A. S. M. E. code for unfired pressure vessels.	Openings for inspection and cleaning are required and should meet specifications of A. S. M. E. code for unfired pressure vessels.
18	6	95	11	1	1		
24	6	185	19	1	1½		
30	7	305	34	1	2		
36	8	450	57	1	2½		
42	10	640	96	1	3		
48	12	1,275	151	2	3		
54	14	1,900	223	3	3		
60	14	3,000	275	3	3		
66	18	4,500	428	3	3		

Table XIII is for discharge pressures up to 125 pounds per square inch.

[1] For automatic start-and-stop service, extra large receivers are recommended to avoid starting too frequently.

All receivers up to 42 by 120 inches inclusive, have screw openings; 48- by 144-inch and larger sizes have flanged inlet and discharge openings with companion flanges.

Receivers are furnished complete with safety valves, pressure gage, handholes or manhole, drain valve and nipple, and base for vertical receivers.

3-10. EQUIPMENT NOTES. The following equipment notes will be placed on the drawings:

a. Air Compressor. Capacity ____ cubic feet of free air per minute at _____ pounds pressure per square inch.

b. Air Receiver. Capacity ____ cubic feet in volume, designed for a pressure of ____ pounds per square inch.

3-11. DESIGN ANALYSIS. The following data will be submitted for approval and publication with plans and specifications:

COMPRESSED AIR SYSTEM

Date ______________________________ Sheet _______ of __________

Engineer __________________________ Checked by ______________

Project: ____

Capacity of each compressor: ________ cubic feet of free air per minute at _____ pressure per square inch gage. Maximum operating pressure of compressors: Systems will operate at _____ p. s. i. gage.

Capacity of air receiver: ___________ cubic feet. Receiver to be designed for a pressure of ______ p. s. i. gage.

Lists of outlets and equipment with the corresponding demand in cubic feet of free air per minute.

Loss of pressure due to friction in the piping system. Gallons of water required per minute to cool the engine and to cool the air in the after-cooler: ______ g. p. m.

SECTION IV - GASFITTING

4-01. GENERAL. This section prescribes basic design criteria for the installation of gas appliances for low-pressure (1/2-pound or less) gas-piping systems to a distance of 5 feet outside building walls. The criteria are based on American Standard ASA Z21.30, Installation of Gas Piping and Gas Appliances in Buildings.

4-02. DRAWINGS. The drawings will show the sizes and arrangement of all piping and the location of valves and the gas-pressure regulator. The piping, in general, will be shown parallel to the lines of the building. Where gas-burning units are located adjacent to each other, a manifold will be provided for the battery, and each end of the manifold will be connected to the gas-distribution system in order to maintain uniform gas pressure at each piece of equipment. On military projects, meters will not be required in buildings when master meters are installed to measure purchased gas, except temporary installations for test purposes or in exchange buildings, or in buildings or private interests and business activities on the post, in accordance with AR 420-80, Repairs and Utilities.

4-03. HEATING VALUE OF GAS. When the exact calorific value of the gas is not known, it will be assumed that manufactured gas has 530 B.t.u. per cubic foot, mixed gas has 800 B.t.u. per cubic foot, and natural gas has 1,000 B.t.u. per cubic foot. Gas contracts are generally written with specific rates per 1,000 cubic feet based on average B.t.u. content per cubic foot of gas.

4-04. GAS CONSUMPTION FOR APPLIANCES. Allowance will be made for any probable change in the specific gravity and heating value of the gas supply when determining the maximum gas consumption in cubic feet per hour. The gas requirements in B.t.u. per hour for some of the common gas appliances are listed in table I. The maximum requirements or connected load, in cubic feet of gas per hour, will be determined in accordance with the following standards:

a. Space Heating. The cubic feet of gas required per hour for space heating will be determined by the formula:

$$\text{Cubic feet of gas per hour, } Q = \frac{\text{B.t.u.}}{E \times CV}$$

Where B.t.u. = Boiler B.t.u. capacity requirements in output per hour.
E = Efficiency (75 percent is a conservative figure for the efficiency of gas-fired spacing-heating equipment).
CV = Calorific value of gas in B.t.u. per cubic foot.

Example: Space-heating requirements for an area are 528,000 B.t.u. per hour. Determine the cubic feet of natural gas per hour that will be required at the boiler.

$$Q = \frac{528,000}{0.75 \times 1,000} = 705 \text{ cubic feet of gas per hour.}$$

b. Domestic-Water Heating. The cubic feet of gas required per hour for domestic-water heating should be determined by the formula:

$$\text{Cubic feet of gas per hour, } Q = \frac{3.8 \times T \times G}{E \times CV}$$

Where G = Quantity of U. S. gallons of water to be heated per hour.
T = Temperature rise in degrees F.
E = Efficiency (75 percent is a conservative figure for the efficiency of gas-fired water heating equipment).
CV = Calorific value of gas in B.t.u. per cubic foot.

Example: Determine the cubic feet of manufactured gas required to heat 100 gallons of water per hour through a temperature rise of 100 degrees F.

$$Q = \frac{8.3 \times 100 \times 100}{0.75 \times 530} = 209 \text{ cubic feet of gas per hour.}$$

Example: Determine the cubic feet of natural gas required to raise 500 gallons of water from 140 degrees F. to 180 degrees F.

$$Q = \frac{8.3 \times 40 \times 500}{0.75 \times 1000} = 221 \text{ cubic feet of gas per hour.}$$

c. Kitchen and Bakery Equipment. The cubic feet of gas required per hour for kitchen and bakery equipment will be determined by the formula:

$$\text{Cubic feet of gas per hour, } Q = \frac{\text{B.t.u.}}{\text{CV}}$$

Where B.t.u. = B.t.u. per hour requirements of the appliances.
CV = Calorific value of gas in B.t.u. per cubic foot.

Example: Determine the cubic feet of natural gas per hour for a messhall kitchen. The B.t.u. per hour requirements for appliances are taken from table I.

	B.t.u. per hour
1 Range, hot top with oven	90,000
1 Range, open top without oven	78,500
1 Range, fry top without oven	50,000
1 Coffee urn, twin, 10-gallon	56,000
1 Bake oven (3 decks)	96,000

The total requirements for the messhall kitchen are 370,500 B.t.u. per hour.

$$Q = \frac{370,500}{1,000} = 370.5 \text{ cubic feet of gas per hour.}$$

Table I - Maximum Gas Demand for Common Gas Appliances

Appliance	Type, size, or capacity	B. t. u. per hour
Broiler	Small	30,000
Broiler	Large	60,000
Broiler and roaster	Combination	66,000
Broiler, toaster, and griddle	Combination	30,000
Coffeemaker, glass	3-burner	18,000
Coffeemaker, glass	4-burner	24,000
Dishwashers	50 racks/hr.	20,000
Deep-fat fryers	45 lb.	50,000
Deep-fat fryers	75 lb.	75,000
Doughnut fryers	200 lb. fat	72,000
Heaters, circulating	Water	25,000
Hot plate, domestic	Per burner	12,500
Kettles, jacketed	20 gal.	75,000
Kettles, jacketed	40 gal.	110,000
Kettles, jacketed	60 gal.	140,000
Kettles, jacketed	100 gal.	180,000
Ovens, baking and roasting	2 decks	100,000
Ovens, baking	3 decks	96,000
Ovens, revolving	4 or 5 trays	210,000
Ovens, revolving	5 or 6 trays	240,000
Ovens, traveling-tray	10 trays	660,000
Ovens, traveling-tray	16 trays	825,000
Ovens, traveling-tray	18 trays	900,000
Ovens, bake	Cabinet type	100,000
Ranges, domestic	4 burner	62,500
Ranges, heavy duty	Hot top with oven	90,000
Ranges, heavy duty	Hot top without oven	45,000
Ranges, heavy duty	Open top with oven	121,500
Ranges, heavy duty	Open top without oven	78,500
Ranges, heavy duty	Fry top with oven	100,000
Ranges, heavy duty	Fry top without oven	50,000
Refrigerator	Gas	3,000
Steam, radiator, gas	Per section	2,000
Stove, bakers	3 rings	40,000
Stove, bakers	4 rings	94,100

Table I - Maximum Gas Demand for Common Gas Appliances -- continued

Appliance	Type, size or capacity	B. t. u. per hour
Steamers, vegetable	2-1/2 to 4 bu.	50,000
Urns, coffee	Single, 5 gal.	28,000
Urns, coffee	Twin, 10 gal.	56,000
Urns, coffee	Twin, 15 gal.	84,000
Water heaters, instantaneous	Automatic:	
	4 gal. per min.	150,000
	6 gal. per min.	225,000
	8 gal. per min.	300,000

For accuracy, the input ratings in B. t. u. per hour will be determined from OCE guide specifications.

4-05. PIPING. Gas piping will be installed in accordance with the American Standard ASA Z21.30, Installation of Gas Piping and Gas Appliances in Buildings. Pipe will be wrought iron or steel. Welded pipe connections are permissible. All piping will be graded not less than 1/4 inch in 15 feet to prevent traps. Horizontal lines will be graded to risers and from the risers to the regulators or appliances. Drips will be provided at points in the line where dirt or condensate may collect.

4-06. FLOW OF GAS IN PIPES. The size of gas pipe required depends on the equivalent length of pipe, the maximum gas consumption to be provided for the allowable loss in pressure from service pipe to appliance, the specific gravity of the gas, and the diversity factor for ranges and refrigerators in quarters. It is recommended that the pressure loss not exceed 0.3-inch water column in any piping system from meter to appliance at the probable maximum gas demand.

a. Connected Load. The most important factor in determining correct pipe size is the probable percentage of the total connected load that will be in use at any one time. This percentage depends upon the characteristics of the project and the number and

kind of gas appliances being installed. The gas company can suggest the proper factor based on previous years of experience.

b. Flow Formula. The flow of gas in pipes is usually computed by the use of the Spitzglass formula.

Formula 1. For gas pressures not exceeding 1-pound gage:

$$Q = 3550K\sqrt{\frac{h}{SL}}$$

Formula 2. For gas pressures exceeding 1 pound gage:

$$Q = 4830K\sqrt{\frac{Pa}{SL}}$$

$$K = \sqrt{\frac{D^5}{1 + \frac{3.6}{D} + 0.03\,D}}$$

Where Q = Standard cubic feet of gas per hour.
D = Inside diameter of pipe, inches.
h = Pressure drop, inches water column.
S = Specific gravity of gas referred to air as 1.0.
L = Length of pipe, feet.
P = Pressure drop, pounds per square inch.
a = Average pressure in pipe, pounds per square inch absolute.
K = Constant for a given size of pipe (see table II).

Table II - Values of K and D for Various Pipe Sizes

Nominal pipe size (inches)	Inside diameter, (inches) *D*	Constant *K*	Nominal pipe size (inches)	Inside diameter, (inches) *D*	Constant *K*
½	0.622	0.117	2½	2.469	6.015
¾	0.824	0.265	3	3.068	10.95
1	1.049	0.532	4	4.026	22.91
1¼	1.61	1.81	6	6.065	67.97
2	2.067	3.67			

Example: Determine the quantity of gas in cubic feet per hour that will flow through a 2-inch pipe 700 feet in length, with gas based on a specific gravity of 0.6, and a pressure drop of 0.3 inch of water column.

Substitute in the Spitzglass formula $Q = 3,500K\sqrt{\frac{h}{SL}}$

The quantity of gas, $Q = 3,550 \times 3.67\sqrt{\frac{0.3}{0.6 \times 700}}$

$= 348$ cubic feet per hour.

Figure 1

CUBIC FEET OF GAS PER HOUR
0.3 INCH PRESSURE DROP 0.6 SPECIFIC GRAVITY

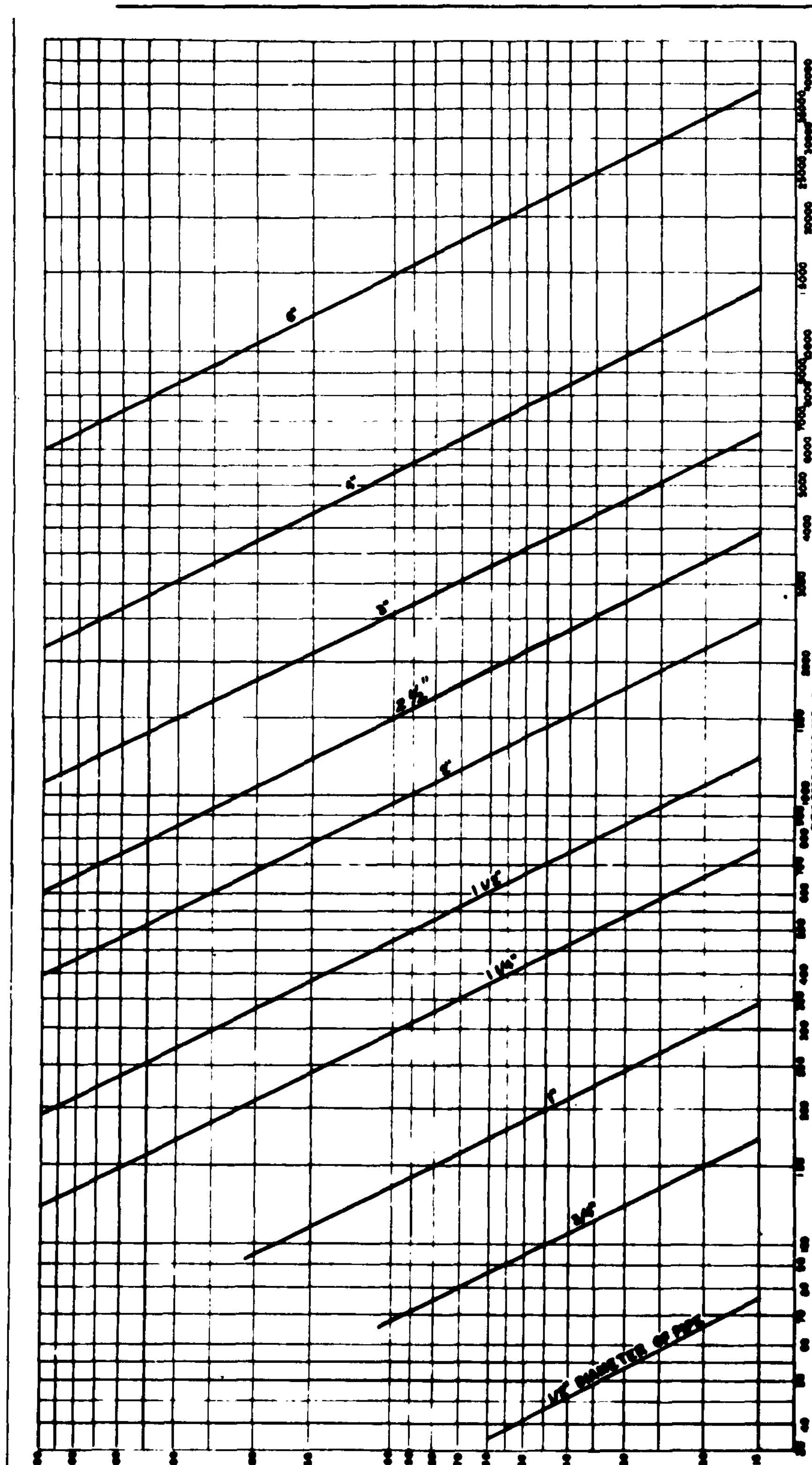


Table III - Cubic Feet of Gas Per Hour 0. 3-Inch Pressure Drop and 0. 6 Specific Gravity

Length of pipe (feet)	Diameter of pipe (inches)									
	½	¾	1	1¼	1½	2	2½	3	4	6
15	76	172	345	750	1, 220	2, 480	3, 900	6, 500	13, 880	38, 700
30	52	120	241	535	850	1, 780	2, 760	4, 700	9, 700	27, 370
45	43	99	199	435	700	1, 475	2, 250	3, 900	7, 900	23, 350
60	38	86	173	380	610	1, 290	1, 950	3, 450	6, 800	19, 330
75	------	77	155	345	545	1, 120	1, 740	3, 000	6, 000	17, 310
90	------	70	141	310	490	1, 000	1, 590	2, 700	5, 500	15, 800
105	------	65	131	285	450	920	1, 470	2, 450	5, 100	14, 620
120	------	------	120	270	420	860	1, 380	2, 300	4, 800	13, 680
150	------	------	109	242	380	780	1, 230	2,090	4, 350	12, 240
180	------	------	100	225	350	720	1, 120	1, 950	4, 000	11, 160
210	------	------	92	205	320	660	1, 040	1, 780	3, 700	10, 330
240	------	------	------	190	300	620	980	1, 680	3, 490	9, 600
270	------	------	------	178	285	580	920	1, 580	3, 250	9, 000
300	------	------	------	170	270	545	870	1, 490	3, 000	8, 500
450	------	------	------	140	226	450	710	1, 230	2, 500	7, 000
600	------	------	------	119	192	390	620	1, 030	2, 130	6, 000

c. Compensation for Pressure Variations. To select the minimum practical pipe size for a single installation, make a simple computation for each branch, beginning at the most distant point of the system, using table III or figure 1. This table and graph automatically compensate for pressure loss through valves and fittings. Gas piping should be large enough to supply the maximum rate for low-pressure distribution with comparatively small differences between the initial and final pressures. Pressure drop is usually expressed in inches of water; if given in ounces per square inch, multiply by 1.73 to convert to inches.

Table IV - Pressure-Drop Multipliers

Drop in pressure (inches of water)	Multiplier	Drop in pressure (inches of water)	Multiplier
0.3	1. 00	0.7	1. 53
0.4	1. 15	0.8	1. 63
0.5	1. 29	0.9	1. 73
0.6	1. 41	1.0	1. 82

d. Pipe-Size Selections. In designing piping layouts, a number of conditions will be kept in mind. Horizontal gas pipes under floors will be kept at a minimum. Piping from a riser to appliances will be proportional to the size of the appliance manifolds, when short runs are anticipated. In those cases where the numbers of valves and fittings are more than ordinary for lateral runs, the flow may be calculated from Spitzglass formula 1 or 2, in table V. The values in table V represent the friction loss in valves and fittings of a size in relation to that of straight pipe of the same diameter.

Table V - Equivalent Length of Pipe in Linear Feet for Valves and Fittings

Fittings	Size of pipe (inches)									
	¾	1	1¼	1½	2	2½	3	4	5	6
90° Elbow	1.00	2.00	2.50	3.00	4.00	5.50	6.50	9.00	12.00	15.00
Tee (run)	0.50	0.75	1.00	1.50	2.00	3.00	3.50	4.50	6.00	7.50
Tee (branch)	2.50	3.50	4.50	6.00	8.00	11.00	13.00	18.00	24.00	30.00
Gate valve	0.50	0.60	0.80	1.00	1.50	2.00	2.50	3.50	5.00	0.60
Globe valve	4.00	5.00	7.50	9.00	12.00	17.00	20.00	28.00	37.00	46.00

4-07. SPECIFIC GRAVITY. The specific gravity of most gases varies between 0.4 and 0.8. The capacity of pipe is affected by this factor inversely as the square root. Table III and figure 1 are based on a specific gravity of 0.6. To convert the figures in this table to other values for a different specific gravity, multiply $\frac{0.6}{\text{specific gravity}}$, where specific gravity is the gravity of the gas for the particular condition.

Table VI - Specific Gravity of Common Gases

Name of gas	Specific gravity
Commercial propane	1.52
Commercial butane	1.95
Natural gases	.60-.75
Manufactured coke oven	.42-.45
Manufactured carburetted water	.55-.70
Sewage gas	.80

Table VII - Multipliers to Convert Gas Flow at 0.6 Specific Gravity to Flow at Other Specific Gravity

Specific gravity	Multiplier	Specific gravity	Multiplier
1.95	0.555	0.80	0.866
1.52	0.628	.70	0.926
1.20	0.707	.60	1.000
1.10	0.740	.50	1.095
1.00	0.775	.40	1.225
.90	0.817		

Table VIII - Equivalent Flow Factors for Converting Cubic Feet of Gas From any Condition of Specific Gravity and Pressure Drop to 0.6 Specific Gravity and 0.3-Inch Pressure Drop

Pressure drop (inches water)	Specific gravity										
	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.52	1.95
0.10	1.41	1.58	1.73	1.86	1.99	2.12	2.24	2.34	2.45	2.76	3.12
0.2	1.01	1.12	1.23	1.32	1.42	1.50	1.58	1.66	1.73	1.95	2.20
0.3	.82	.91	1.00	1.08	1.15	1.23	1.29	1.35	1.41	1.59	1.80
0.4	.71	.79	.87	.93	1.00	1.06	1.12	1.17	1.23	1.38	1.56
0.5	.63	.71	.78	.84	.90	.95	1.00	1.05	1.09	1.23	1.39
0.6	.58	.65	.71	.76	.82	.87	.91	.96	1.00	1.13	1.27
0.7	.53	.60	.66	.71	.76	.80	.85	.89	.93	1.04	1.18
0.8	.50	.56	.61	.66	.71	.75	.79	.83	.87	.97	1.10
0.9	.47	.53	.58	.62	.67	.71	.75	.78	.82	.92	1.04
1.0	.45	.50	.55	.59	.63	.64	.71	.77	.78	.87	.99

Example: Determine the proper size pipe to carry 2,000 cubic feet of gas per hour a distance of 200 feet, with a pressure drop of 0.5 inch, and a specific gravity of 0.4.

Refer to table VIII and read the factor 0.63 at 0.5-inch pressure drop and 0.4 specific gravity.

2,000 x 0.63 = 1,260 cubic feet of gas.

Now use figure 1 for 1,260 cubic feet of gas and for 200 feet of pipe and find that a 3-inch diameter pipe will be required to carry the equivalent flow of gas per hour.

4-08. FLUE OR VENT CONNECTIONS. The minimum requirements established by the American Gas Association include the following recommended practices in regard to the installation of flues or vents.

a. Appliances Requiring Venting. Appliances of the following types will be flue- or vent-connected or provided with other approved means of exhausting the flue gases to the outside atmosphere:

(1) Central-heating appliances excluding steam- and hot-water boilers, warm-air furnaces, floor furnaces, and vented recessed heaters.

(2) Unit heaters and duct furnaces.

(3) Gas-fired incinerators.

(4) Water heaters with inputs of more than 5,000 B.t.u. per hour.

(5) Room heaters approved for vented use only.

(6) Appliances equipped with gas-conversion burners.

(7) Appliances with draft hoods supplied by the appliance manufacturer (except room heaters approved for vented or unvented use).

(8) Unapproved appliances.

b. Appliances Not Requiring Venting.

(1) Approved gas ranges.

(2) Approved hotplates and laundry stoves.

(3) Approved domestic clothes dryers.

(4) Approved water heaters with inputs of not more than 5,000 B.t.u. per hour.[1]

(5) Approved gas refrigerators.[1]

(6) Counter appliances.[1]

(7) Other appliances approved for vented use and not provided with flue collars.[1]

[1] When any or all of the appliances starred above are installed so that the aggregate input rating exceeds 30 B.t.u. per hour per cubic foot of room or space in which they are installed, they will be flue- or vent-connected or provided with approved means for exhausting the flue gases to the outside atmosphere. Where the room or space in which they are installed is directly connected to another room or space by a doorway, archway, or other opening of comparable size that cannot be closed, the volume of such adjacent room or space may be included in the calculations.

c. Draft Hood. Every vented appliance, except incinerators, dual oven-type combination ranges, and units designed for power burners or for forced venting, will have a draft hood.

d. Vent Size. The vent pipe or connection will not be smaller than the size indicated by the vent collar of the appliance. Where appliance has more than one vent, the vent pipe will equal the combined area of the vents for which it acts as a common connection to the flue.

e. Dampers. No damper will be placed in any flue connection between the appliance and the draft hood. Except for fixed baffles, dampers will not be installed between a draft hood and a chimney. Dampers for all open fireplaces will be specified and shown on the plans. These dampers conserve room heat when the fireplace is not in use.

4-09. FLUE REQUIREMENTS. Flue pipes, also called vent pipes, will be constructed and connected so that the best possible draft may be obtained and so that the draft may be reasonably uniform. The draft will generally be sufficient if the following conditions are considered.

a. Length of Flue. The flue connector must not be unduly long. The length for a satisfactory flue pipe depends upon the nature

of the appliance, the quantity and temperature of the flue products, and the probable available draft. The disadvantages of a long horizontal flue are undue cooling of the products of combustion and friction for the passage of flue gases. The maximum length of horizontal run will not exceed 75 percent of the height of the flue vent.

b. Bends. Friction in the flow of gaseous products can be kept at a minimum by eliminating unnecessary bends. Bends will be 45-degree instead of 90-degree pattern wherever possible. Long-radius bends will be considered rather than short-radius bends.

c. Chimney Connection and Pitch. No chimney connection will enter the flue closer than 1 foot from the bottom, nor will the connection protrude within the flue, obstructing the flow of gas in the chimney. A gas-appliance vent pipe and a smoke pipe from an appliance burning another fuel may be connected into the same flue through separate openings on different levels, or may be connected through a single opening by a wye-shaped fitting located as close as practicable to the chimney. All vents will be connected to a chimney by a slip joint with the thimble cemented to the chimney wall, but not extending beyond the lining. When a vent connection passes through a wall, partition, or floor made of combustible material, an approved ventilated or insulated sleeve will be installed. The vent pipe will maintain an upward pitch or rise of at least 1/4 inch per foot from the appliance to the flue or chimney. For runs longer than 15 feet, the pitch will be at least 1/2 inch per foot. A vent connection will be securely supported at intervals of not less than 6 feet.

d. Types of Flues. Type A constructed chimney is built of brick, stone, solid-block masonry, or concrete. Such chimneys, intended for gas appliances, will be lined with a terra-cotta or fire-clay flue, set in acid- and moisture-resistant mortar. Type A chimneys are designed to withstand the high temperature produced by coal or oil fires, and to resist disintegration by ordinary flue products. Offsets retard the draft and offer a place for debris to accumulate, decreasing the efficiency of the chimney. When the direction of the chimney and flue must change, it will not depart by more than 30 degrees from the vertical. The ends of the flue linings forming offsets will be carefully cut, fitted, and set. Each length of flue will be placed in position and the brick will be laid around it. A tight-fitting door will be placed near the bottom of the chimney to provide means for cleaning out the chimney and inspecting the flue.

Type B flues constructed of noncombustible, corrosion-resistant material save money and construction space. They are simple to install and are therefore particularly useful for emergency construction. Since gas appliances produce lower flue temperature than appliances using other fuels, they do not require the construction of expensive flues. The National Board of Fire Underwriters has authorized a dass of flue known as type B, which may be used with all gas appliances except gas incinerators. These flues are not suitable for use with liquid or solid-fuel appliances. They will be permanently and plainly labeled:

"THIS FLUE IS FOR GAS-BURNING APPLIANCES ONLY". The label will be attached in plain sight at a point near the junction of the vent pipe and the vertical flue. Flue material used in type B construction will conform to the requirements of the National Board of Fire Underwriters. The Underwriters' Laboratories, Inc., label will be accepted as evidence of such conformance. In lieu of the label, the contractor may submit a written certificate from any nationally recognized testing agency adequately equipped and competent to perform such services, stating that the flue material has been tested and conforms to the standards of the National Board of Fire Underwriters, including methods of test of the Underwriters' Laboratories, Inc. Complete information on type B flues will be found in the National Board of Fire Underwriters' Building Code. Joints in type B flues will be made gastight. Suitable provision will be made to prevent mechanical injury to type B flues where they extend through walls, floors, or roofs. The pitch of the flue through an attic will not be less than 45 degrees from the horizontal. The flue will run continuously through the roof. This applies particularly to appliances installed in the attic. Because of the relatively small size of many type B flues (4 to 6 inches) the vent cap will have a wire screen to prevent birds from building nests in the opening during the summer when the appliance is not in use. To avoid making several holes through the roof, it is common and satisfactory practice to tie several flues together by means of a wye fitting in the attic. If more than one floor furnace is to be vented by a single flue, the connections may be made under the floor of the house, provided the vent connections are straight, without elbows, and can be pitched 1/2 inch per foot of horizontal distance. Horizontal distances will not exceed 20 feet, and preferably will be kept to 15 feet or less. Where a single

flue is used for a gas water heater and several other appliances, provision will be made for a 4-inch tee opening to take the water-heater flue. This permits the use of practically any size water heater. A 3-inch tee limits the size of appliances that may be used.

e. Clearance. Minimum clearances from combustible construction to flue or vent connections are shown in table IX.

f. Size of Flues. The size of flues required with gas-burning appliances is given in the following figures. Figure 2 supplies data to establish the proper size flue, either type A or type B, to which a vent pipe will be connected. A flue will not be installed smaller than specified in this figure nor smaller than the size required by the vent collar on the appliance. Capacities in this figure will be decreased 4 percent for each 1,000 feet above sea level that the building site is located. Where several appliances are connected to the same flue, the flue will be large enough to take care of the entire load:

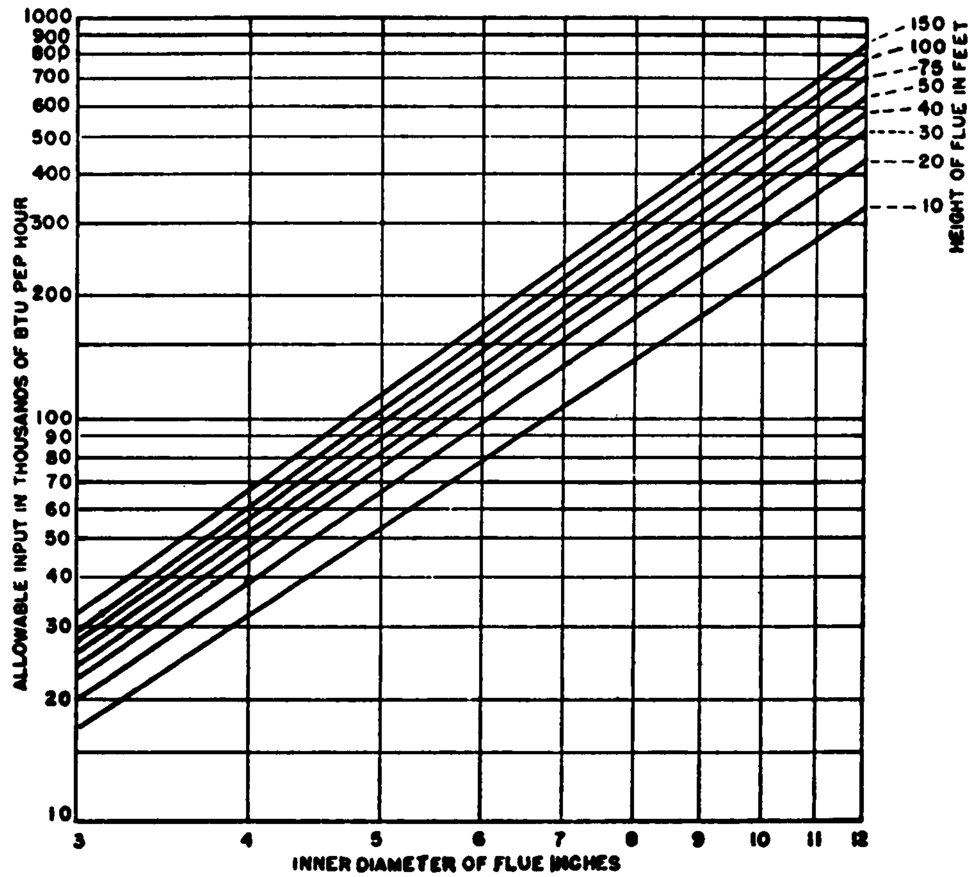
Table IX - Flue- or Vent-Connector Clearances for Appliances

Appliance	Minimum distance from combustible construction	
	Metal flue or vent connectors	Type B flue or vent connectors
Boiler	6 inches	1 inch.
Warm air furnace	6 inches	1 inch.
Water heater	6 inches	1 inch.
Room heater	6 inches	1 inch.[1]
Floor furnace	9 inches	3 inches.
Incinerator	18 inches	Not permitted.

[1] 3 inches for a distance of not less than 3 feet from outlet of the draft hood. Beyond 3 feet the minimum clearance is 1 inch.

Figure 2

CIRCULAR FLUES FOR DOMESTIC GAS APPLIANCES WITH DRAFT HOODS FOR TYPE A AND B CONSTRUCTION

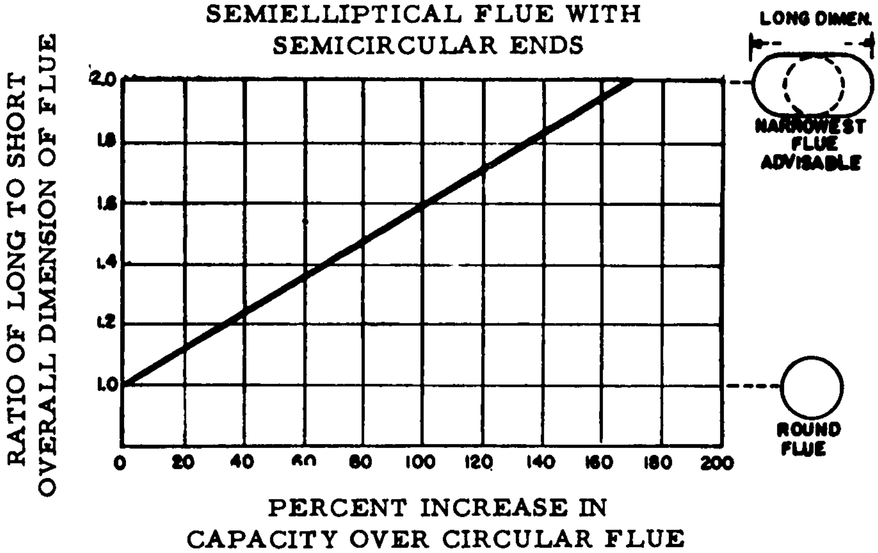


For each elbow in excess of two, reduce the allowable horizontal run by a length in feet equal to the diameter of the elbow in inches.

A comparison between circular, rectangular, and elliptical flues is illustrated.

Figure 3

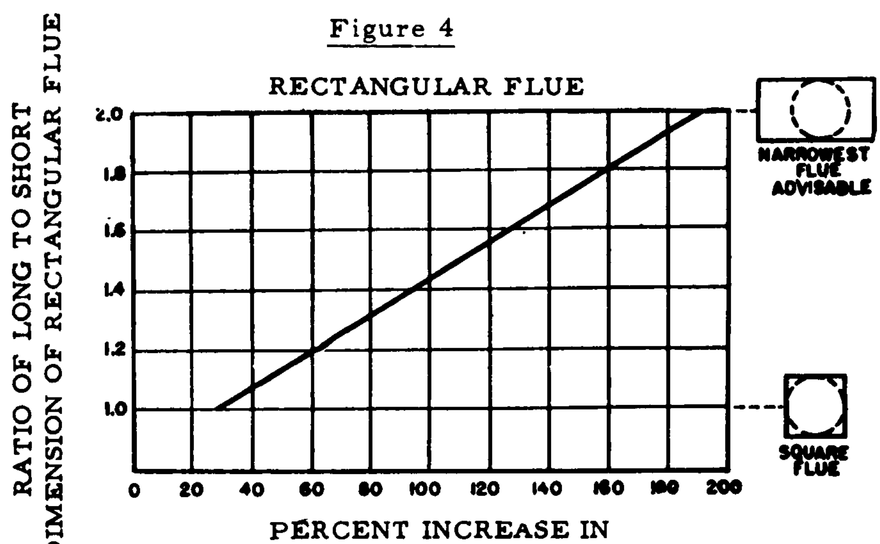
SEMIELLIPTICAL FLUE WITH SEMICIRCULAR ENDS



Capacity of a semielliptical flue with semicircular ends, having its minimum width equal to the diameter of a circular flue, compared with the capacity of the circular flue.

Figure 4

RECTANGULAR FLUE



Capacity of a rectangular flue, having its minimum width equal to the diameter of a circular flue, compared with the capacity of the circular flue.

Example: Given an input of 100, 000 B.t.u. per hour for a domestic appliance and a flue height of 20 feet, the horizontal run may be circular, but the flue is limited to a 4-inch width to fit within a wall. What will be the dimensions of the run and of the flue?

From figure 2, a circular flue and run of 6 inches is sufficient. This fixes the dimension of the run. Figure 2 also shows that a 4-inch circular flue and run would have a capacity of 38, 000 B.t.u. per hour for a flue height of 20 feet. The flue cross section must be elongated to give an additional 62, 000 B.t.u. per hour capacity.

$$\frac{62,000}{38,000} \times 100 \text{ percent} = 163 \text{ percent or}$$

the increase needed beyond the capacity of the 4-inch circular flue. If a semi-elliptical flue is used, figure 3 shows that a flue with a ratio of 2 between its long and short dimensions is satisfactory. The flue will be 4 by 8 inches. If a rectangular flue is used, figure 4 shows that the flue will have dimensions of 4 by 7.3 inches. The next largest conventional size will be used.

g. Height. The flue or vent will extend high enough above the building or other neighboring obstruction so that no downward-flowing wind from any direction will strike the flue or vent from an angle above horizontal. Unless the obstruction is of great magnitude, it is the usual experience that a flue or vent extended at least 2 feet above flat roofs or the highest part of wall parapets and peaked roofs within 30 feet will be reasonably free from downdrafts.

4-10. GAS-PRESSURE REGULATORS. Regardless of the pressure of gas in the transmission mains, it is customary to reduce the pressure to 5 inches of water column for use in buildings. The outlet pressure should not vary more than 1/2 inch of water column from the pressure setting of the regulator. Regulators will be equipped with vent pipes leading outside the building. A good pressure regulator will fill the following requirements:

Maintain a uniform operating pressure at all appliances independent of the number of appliances in use.

Prevent the possibility of dangerous overpressure on the house piping and appliances.

Maintain a low pressure for metering where meters are required and still give satisfactory pressure at appliances.

Be able to respond to quick changes in rate of flow occasioned by thermostatic valves, instantaneous water heaters, and other similar appliances.

Maintain these characteristics over a long period of time in spite of changing inlet pressure and other variables.

4-11. DESIGN ANALYSIS. Design analysis will be submitted with drawings to permit review and the issue of instructions. The following data are taken from examples given in the text for the purpose of illustrating an acceptable method for submitting design data:

GAS SERVICE

Date ____________________ Sheet ______ of ______
Engineer ____________________ Checked by __________
Post ____________________ Project __________
Minimum service pressure at building ___ per square inch.
Pressure loss in main 0.3-inch water column.
Length of pipe from main to most distant outlet 300 feet.

Risers:

Floors	1	2	3	4	5	6
Height, feet	5	15	25	35	45	55
Pipe, size, inches	2	2	2	1-1/2	1-1/2	1-1/4

Gas consumption, cubic feet:

Ranges and refrigerators	756	360	504	378	252	126
Range and refrigerator:						
Connected load	340	309	272	227	176	126
Space heating	240	200	160	120	80	40
Total load	580	509	432	347	256	166

Connected load, cubic feet:

Main	A-B	B-C	C-D	D-Regulator
No. ranges and refriegerators	12	24	36	48
Range and refrigerator:				
Connected load	499	696	907	1,089
Space heating	480	960	1,440	1,920
Total load	979	1,656	2,347	3,009
Length of pipe, feet	110	70	50	10
Pipe size, Inches	3	3	3	3

Note: Sketch of gas piping layout shown on figure 1.

FOR THE CHIEF OF ENGINEERS:

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